UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service

Proceedings of the ARS-SCS Workshop
on
LAND LEVELING FOR DRAINAGE AND IRRIGATION

With Participation by
State Agricultural Experiment Stations and
Other Agencies

Held at
Louisiana State Univeristy
Baton Rouge, Louisiana
May 23-25, 1961

FOREWORD

A report of a workshop on land leveling, grading, and smoothing for surface drainage, held at Louisiana State University, Baton Rouge, Louisiana, May 23-25, 1961 is presented herewith. This workshop was scheduled following discussions in previous months between certain personnel of the Agricultural Research Service and the Soil Conservation Service of the U. S. Department of Agriculture.

The purposes of the workshop were threefold:

1. To provide a medium for field personnel in the Soil Conservation Service to discuss problems in surface drainage with appropriate personnel in the Agricultural Research Service and the State Agricultural Experiment Stations.

2. To permit the research personnel to report directly to SCS field personnel current progress in surface drainage research activities.

3. To bring appropriate SCS personnel together for discussions of mutual problems in the field of surface drainage.

The program was designed to achieve these objectives. Part of the program consisted of the presentation of papers. Each of these papers is reproduced herewith in the form prepared by the author. Much of the time was utilized for informal discussions. The major items covered are given in outline form following the papers referred to above.

Expressions from various individuals indicated the workshop was very successful in accomplishing the stated objectives.

Respectfully submitted

John R. Carreker
RIL, SWC-ARS, and
General Secretary of Workshop

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on
Land Leveling for Drainage and Irrigation
May 23-25, 1961

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PLACE OF LAND GRADING AND SMOOTHING IN SURFACE DRAINAGE SYSTEMS

by

Lewis W. Herndon[1]

The present concept of a good surface drainage system is quite different from what it was in the early part of the century. Most of the plans for drainage developments prepared in the period 1907-1927 consisted of the channel improvements which are the first component of drainage disposal systems - the large group main ditches and laterals - but little was done to extend the system on to the farm and individual field.

Some farmers cut some ditches to more effectively drain their fields but for the most part the lack of field drainage facilities was one of the weaknesses of many drainage systems.

It has been recognized that the full benefits of major drainage improvements can be realized only by providing for the removal of excess water from all of the field - from each row and from the most remote part of the row from the drainage ditch. At first this was done by extending the lateral ditch system onto the farm and into the natural low areas within each field. This has been further improved and developed into a complete system of laterals and surface field ditches oriented in such a way that each row can discharge its excess water into a ditch without erosion and in adequate time to prevent crop damage.

In irregular, moundy, or undulating topography this system of providing a ditch to all low areas and for all crop rows resulted in a disproportionate number of ditches. In many cases it has been difficult to convince farmers of the necessity for installation of so many ditches in their fields. With the growing mechanization of farming, we have realized that some of the ditches had to go and those remaining had to be squared up with the field as far as practicable.

But increased mechanization and the necessity for high and efficient production also demand better drainage. The only answer - and it is obvious - is to improve on the topography. Fortunately many areas where irregularities in topography are very severe and require heavy cuts to improve are in alluvial valleys where soils are deep and fertile. In other areas where deep cuts are required - moundy phase soils - a method has been found for doing the necessary work without greatly affecting the quality of the soil profile.

1/ Drainage Engineer, SCS, E & WP, Ft. Worth, Texas.

We now feel that one of these two practices - land smoothing (removing irregularities without changing the overall land slope) or land grading (reshaping the ground surface to planned grades) is the final step in the installation of a completely adequate surface drainage system. The topographic situation and type of farming will dictate the practice which is indicated. For special conditions and certain types of farming, the practice of bedding (crowning or corrugating) may be preferable to either smoothing or grading.

Improving the surface by one of the land forming practices permits the elimination of some surface field ditches - by increasing the recommended minimum distance between them - and the better location of the remaining ditches. It also improves the capability of the land to fully utilize rainfall and to dispose more effectively of the excess without ponding.

Of the two practices - land smoothing and land grading - the land grading is by far the more effective. It is also the more expensive and may cost from 5 to 10 times as much as land smoothing. In fact, a job of land smoothing is the final operation in a land grading job.

In spite of our conviction that these are good practices and are a decided improvement over complete reliance on ditches and row direction for adequate drainage there are some problems connected with their use and some criteria regarding design and subsequent ditch location about which we need further information. This morning you had a rather complete discussion of these problems and specific criteria needed. It is hoped that working together we can soon solve most of these problems and develop more specific criteria.

LAND LEVELING AND SMOOTHING IN ARKANSAS

by

Elwin D. Butler 1/

EXTENT AND GENERAL LOCATION

The extent and location of the areas that have been land leveled to a planned grade are shown on the attached map, Figure 1. Land smoothing is also shown. All land leveling to a planned grade has been primarily for irrigation in Arkansas, although benefits are also received from improved drainage.

USE BY SOILS AND CROPS

Cotton, soybeans, and rice are the principal crops benefited. Most of the land leveling has benefited cotton and soybeans. Most of the land smoothing has benefited rice and soybeans.

RATE OF PROGRESS

Land leveling has progressed at the rate of about 12,000 to 14,000 acres per year for the past 6 years. Land smoothing has been accomplished at the rate of about 40,000 acres per year.

DESIGN CRITERIA USED

General. All precision leveling jobs have been planned with both irrigation and drainage in mind. The ACP cost-sharing practice that assists farmers in Arkansas is on land leveling for irrigation. This assistance is 8¢ per cubic yard, not to exceed $35 per acre. There is a $5 per acre payment for land smoothing for drainage.

Arkansas land leveling design criteria are pointed toward providing the highest practical irrigation efficiency.

The plane method of leveling is used. Since quite often the natural overall slope of the field is near the planned irrigation slope and cross slope, the plane of best fit is calculated on each segment of a field.

Minimum and Maximum Grades and Cross Slope. Minimum and maximum irrigation grades are 0.1 percent to 0.3 percent. Cross slope must not exceed irrigation slope, and quite often is equal to zero.

Row Lengths Used for Different Soils. Minimum and maximum row lengths are determined by drainage requirements. The following criteria are from our Drainage Guide:

1/ ~~State Conservation~~ Engineer, SCS, Little Rock, Arkansas

Row Length[2/] - Feet

Soil Unit	Land Leveling	Land Smoothing: Land Slope less than .1%	Land Smoothing: Land Slope .1% and over
3a Deep, fine textured, very slowly permeable, moderately wet soils.	Maximum 1320	Maximum 660	Maximum 1320
4, 4al, 4a Deep, fine textured, slowly permeable soils, including slightly and moderately wet soils.	Maximum 1320	Maximum 880	Maximum 1320
5a, 5al Deep, medium textured, very slowly permeable, slightly to moderately wet soils.	Maximum 1320	Maximum 660	Maximum 1320
6al Deep, medium textured, slowly permeable, slightly wet soils.	Maximum 1320	Maximum 880	Maximum 1320
8al, 8a Deep, medium textured, slowly permeable, slightly to moderately wet soils.	Maximum 1320	Maximum 880	Maximum 1320

Limit on Cuts and Fills. We provide no limit on cuts and fills in our specifications, although personnel are cautioned to keep them in mind when planning the leveling job. We recommend that maximum cut not exceed one half the depth of topsoil unless the cut areas are treated to restore productivity.

Arrangement of Ditches on Graded Fields. A drainage system is planned and installed in conjunction with each land leveling job. Generally, fields are bounded by planned laterals and surface field ditches. Normally, the laterals are parallel to each other. Surface field ditches are perpendicular to the laterals.

Tolerance in Construction. Leveling must be such that water will not be impounded more than 0.1 foot deep at any place. Finished grades must not vary from planned grade by more than 0.1 foot.

2/ Locate surface field ditches in depressions and at end of rows, or at maximum spacing below.

PROBLEMS

One of our problems is deciding what is an acceptable method of planning land leveling. Some engineers think that present Arkansas SCS specifications require too high a degree of leveling. They say that a much less expensive method of leveling can be planned than the plane method which will result in improved drainage and still result in acceptable irrigation efficiency. A warped surface can be planned, for instance, which gives continuous but variable row grades and side fall. By adhering closer to the natural slope of the field, less yardage need be moved. This will require grades in excess of our present 0.3 percent maximum on some of our terrain. It could also result in difficulty in locating irrigation supply ditches. We believe that any method selected must give acceptable irrigation efficiency as well as improved drainage.

We need to know minimum and maximum grades and cross slopes by soil types that will result in good drainage, acceptable irrigation efficiency, and on which erosion will not be an objectionable problem.

Yield decreases on cut and fill areas are variable. We need to know by soil types how to predict them.

We need to know what row lengths will result in good drainage and acceptable irrigation efficiency, considering slope and type of soil.

There is a problem of how to calculate the rate of runoff on leveled land for design of culverts and pipe drops. When surface depressions are eliminated, there appears to be a considerable increase in runoff that overtops culverts and pipe drops designed to carry the conventional design runoff.

PROBLEMS ENCOUNTERED BY THE SCS IN LAND GRADING AND LAND SMOOTHING FOR DRAINAGE IN LOUISIANA

by

K. V. Stewart[1/]

The term "land forming" is commonly used outside the SCS to cover the field of land grading for drainage and land leveling for irrigation. This discussion is limited to forms of land grading for drainage. The definitions used in Louisiana by the SCS and covered in this statement, are as follows:

1. Land Grading - Re-shaping the ground surface by grading to planned grades. This practice requires a detailed engineering survey and layout. The purpose is for improved surface drainage.

2. Land Smoothing - Removing minor irregularities of the land surface without altering the general topographic pattern. Smoothing is usually done with bulldozers or scrapers and does not require a detailed engineering survey. This does not include routine floating with a land plane, except as a finishing operation. The purpose is for improved surface drainage.

3. Crowning - Shaping an area of land greater than 60' in width, and of any length, to provide continuous surface slopes across the crowned area. The land slope, in the directoon of the centerline axis of each crown, is not changed in the crowning operation. The side boundaries of each crown are formed by some type of surface ditch. Crowning is commonly used in connection with the split ditch type of drainage system used in the sugarcane section of Louisiana for many years. The purpose is to improve surface drainage.

4. Corrugating - Corrugating is shaping adjacent areas of land (usually pasture or hay land) to provide continuous surface cross slopes from the longitudinal center of the corrugation to a dead furrow on each side. The land slope in the direction of the centerline axis is not changed. Dead furrows carry surface runoff to field ditches.

The type of grading used depends upon the soil type, the farming area, and the habits farmers have developed over the years.

Land grading is mostly used in northeast Louisiana, in the Mississippi Delta Lands, where the general crops such as cotton, corn and soybeans are grown. Here, land grading is usually done in connection with the conventional pattern V-type field ditch and V-type lateral ditch surface drainage system. The dimensions of the graded areas are usually determined by the required location of the drainage ditches.

1/ State Conservation Engineer, SCS, Alexandria, Louisiana

The recommended row lengths, on ungraded land, on gumbo or buckshot soils such as Miller clay or Sharkey clay, varies from 300' to 400'; on mixed soils such as Miller or Mhoon silty clay loams, from 400' to 600'; and on sandy soils such as Yahola or Commerce sandy loams, varies from 600 to 1000'.

The recommended row lengths given above can be increased 200' on land which has been graded. The maximum recommended length of field ditches (usually V-type ditches which carry row water) ranges from 1000' to 1200'. The recommended optimum distance ranges from 600' to 800'.

Where the specialized crop, sugarcane, is grown, the most common practice is land crowning. Crowning is commonly used in connection with split ditches in a sugarcane drainage system previously installed. It is also used in the sugarcane area on permanent pasture land in the gumbo or buckshot clay soils. This practice was developed by I. L. Saveson, after drainage research, and has spread considerably in the sugarcane section.

Land smoothing is done mostly in the Red River Valley and the Mississippi Delta section of Louisiana. The need for a few row drains and surface field ditches is usually eliminated in the land smoothing process.

Corrugating is used mostly on flat, poorly drained, and silty soils in the Red River Valley, and in the loessial areas of Louisiana. It is usually used where a greater surface slope is required for surface drainage. This practice is not ordinarily used for row crops.

Copies of SCS specifications for the four practices listed at the beginning of this discussion are attached.

Experience to date has indicated that not much difficulty is encountered in making cuts and fills on various soils, due to the fact that most grading operations are done on alluvial soils. As a general rule, it has been noted that crop yields have been reduced more on filled areas than on cut areas. We think this is probably due to the perched water table caused by the "bowl" underlying the filled area.

It has also been noted that the maximum allowable row lengths seems to vary by areas in the state. As an example, the row lengths in the Ouachita Valley in the vicinity of Monroe, Louisiana, apparently can be considerably greater than the row lengths in the Red River Valley or the Mississippi Valley, particularly on sandy soils. This is probably due to the grain size and the mixtures of clay or silt with the sands. We think that row grades in the Ouachita Valley can be as steep as .5' to .6' per 100', and row lengths as great as one-half mile are permissible. In certain areas of the Mississippi Delta and the Red River Valley, these lengths and grades would be excessive.

There is considerable discussion inside the SCS in regard to optimum depth of surface field ditches used in connection with land grading. We originally started out on ungraded land with a minimum depth of one foot. After some years of experience, we reduced this minimum to 0.8'. Based on our observations of land grading, we now think that a minimum depth of 0.6' may be desirable.

The limited research I. L. Saveson has done to date on land grading in the sugarcane area indicates that this practice is economically feasible, even though cost runs as high as $80.00 to $100.00 per acre. His research on land crowning in the sugarcane area has proved that practice to be economical beyond doubt. In our opinion, land smoothing has proved economical, but we have no research data to back this up. As a general rule, we look on land smoothing as an interim practice until the land owner will install land grading at some future date. Corrugating is usually limited to grasslands. We do not have research information on this practice.

We believe research on land grading for drainage should include all three general soils types, i.e. sandy or "front" land, "mixed" lands, and "buckshots" or "gumbos". Our experience has indicated recommendations will vary considerably on these soils. Also, an upper limit of grade of 3" per 100' for experimental work on all soils is questionable.

The practices of land grading, land smoothing, crowning and corrugating, are being used in Louisiana to improve surface drainage of agricultural lands. SCS records show that approximately 20,000 acres of land grading and land smoothing, and approximately 33,000 acres of crowning and corrugating have been used to date.

It may be interesting to note that land smoothing for irrigation purposes in Louisiana to date has been accomplished on approximately 640,000 acres.

LAND LEVELING, LAND GRADING AND LAND SMOOTHING
IN MISSISSIPPI

by

Robert L. Tisdale 1/

Up to the present time, all land leveling and land grading in Mississippi has been located in the Delta Area of the state. The climate, soils, and topography are well adapted to these practices. The average annual rainfall varies from about 60 inches on the coast to about 50 inches in the Delta. Numerous drought periods occur during the average growing season regardless of high annual rainfall. We feel that these weather conditions require that about equal emphasis be placed on drainage and irrigation in our design criteria. The practice is referred to in Mississippi as land leveling.

During the past six years approximately 28,000 acres of row crop land has been land leveled in the Delta Area of Mississippi. During the period July 1, 1959 through June 30, 1960 there were approximately 3,497 acres land leveled. The trend in number of acres land leveled each year for the past three years is fairly constant.

Land leveling is not confined to any one soil type. All soils respond well when cut limitations are observed. Cotton, soybeans and rice are the primary crops for which land is leveled.

Land smoothing is used extensively through the Delta Area and to some extent in the hill area. There were approximately 11,984 acres of land smoothing done in the Delta Area during the period of July 1, 1959 to June 30, 1960.

Row lengths vary from 300 feet for deep sands to 1,000 feet for heavy clay soils. The maximum slope in row direction is 0.30 foot per 100 feet on sandy loam soil and 0.50 foot per 100 feet on mixed or heavy clay soils. The minimum slope in row direction is 0.10 foot per 100 feet for all soils. No cross slopes are allowed to exceed row direction slopes. Soils of the Delta have been arranged into six major groups with maximum cuts ranging from 0.3 to 1.5 feet and soils on which the maximum depth of cut should be determined by on-site investigations. Land leveled fields have an adequate drainage disposal system designed to remove 3 inches of surplus run-off water in 24 hours. These ditches have a flat side slope of 4 to 1 or less. Fields are constructed with a tolerance not to exceed 0.1 foot above or below the design elevation for each station and with the same tolerance between stations.

Farms that began a land leveling program and have leveled most of their fields except the limited cut areas are finding it difficult to finish their land grading program because of limited cuts. Further study of limited cut criteria would be useful.

1/ Agricultural Engineer, SCS, Greenville, Mississippi.

A small number of furrow irrigation studies were run in the Delta Area during the last two years that indicate sandy loams and silt loams will absorb approximately $2\frac{1}{2}$ to 3 inches of water starting with 50% moisture deficiency to root zone depth. Infiltration completely stops after about 5 hours of irrigation time.

Clay soils having a high shrink-swell factor will readily absorb from 3 to 5" of water when cracks are well developed. Further furrow irrigation studies are planned.

In a few instances land leveling has reduced the yields temporarily. Most of yield reductions has occurred on fill areas. It usually takes from 1 to 3 years before yields are back to normal on these areas. The average yields for most land leveled fields are increased. The depression of yields are caused by compaction that results from carrying on land leveling operations when the soil is too wet. Remarkable cotton and soybean yields result when irrigation is practiced on land leveled fields during dry years. This is especially evident when droughts occur during crop fruiting season and irrigation is practiced.

Where land leveling is carried out on a large scale and over a number of years, overall plans are developed to guide the year to year development so that a well integrated and efficient irrigation and drainage system will result when the plans are completed. Irrigation flumes are included in the plans where open ditches and siphon tubes are planned to be used in irrigation and adequate outlet drainage ditches are planned for tail or interceptor ditches to insure that runoff water will be moved from the ends of crop rows.

Field surfaces have to be planed and tail ditches maintained each year. Shallow tail ditches with trapezoidal-shaped cross sections, constructed with earth moving pans, have a longer life than ditches with V-shaped cross sections. In some instances it is necessary to do corrective work the second year after leveling on some fill areas that settle.

To discuss all the facts of our land leveling, smoothing and grading program would take much longer than the time allotted.

We are convinced that land leveling is an excellent practice where needed and will pay for itself several times by resulting in improved drainage, irrigation, farm management and efficiency of farm machinery.

LAND SMOOTHING, LAND GRADING, AND LAND LEVELING IN MISSOURI

by

W. S. Culpepper[1/]

The State of Missouri is comprised of about 44,500,000 acres, of which approximately 14,500,000 acres or 1/3 is Ozark or border Ozark area having steep to very steep topography. Of the remaining 30,000,000 acres in the state about 16,000,000 acres are cropland. Of this 16,000,000 acres of cropland about 28% or 4,500,000 acres have a wetness problem. According to the best estimates available, it is practical and feasible to reduce the wetness problems by land smoothing or land grading on 2,500,000 acres under the present agricultural economy. Of this acreage an estimated 1,500,000 acres need smoothing and 1,000,000 need land grading.

Missouri has an average annual rainfall of from about 31" in the northwest part of the state to 45" in the southeast part. The rainfall distribution is somewhat erratic. For example, it is not unusual for floods and droughts to prevail in the same area in a single year, yet rainfall distribution many times is very good for crop production for several years in seccession. Because of these conditions it is difficult to analyze and estimate the total need in the state for land leveling for irrigation. Actually the cost allocation for establishing this practice is estimated to approximate 75% for drainage and 25% for irrigation. There are 84,000 acres in the state on which leveling for combined irrigation and drainage is believed practical and feasible. This makes a total of 2,584,000 acres of the 4,500,000 that need drainage improvement.

These practices (land smoothing, land grading and land leveling) have been used in the state only for the last 5 or 6 years and have been adopted by landowners at a slow rate. The reason for the slow rate of adoption appears to be (1) nature of farmers to be slow in adopting new practices, (2) lack of proper type and amount of required equipment by contractors or farmers, (3) high construction cost, particularly for grading and leveling, (4) limited number of trained technicians for survey, design and layout for grading and leveling, (5) lack of firm economic return information on investments, (6) short construction season for this type of work, and (7) lack of research on which to base design criteria for grading and leveling.

To illustrate the slow rate of adoption by farmers in Missouri, for example, our records for 1960 show establishment of 44,522 acres of land smoothing, 1,715 acres of land grading, and 9,700 acres of land leveling or a total for the three practices of 55,937 acres. It is expected, however, that establishment of these practices will increase materially during subsequent years. During 1961 an increase of 25% to 50% is expected over 1960. Most of these practices established to date have been in the Southeast Missouri Delta Area with a limited amount in the Mississippi and Missouri River bottoms along with a small acreage of land smoothing only done in upland flat Putnam soils area of the state.

1/ State Conservation Engineer, SCS, Columbia, Missouri

DESIGN CRITERIA AND PROBLEMS

Land Smoothing

A. Recommended as a permanent practice in flat upland (0.1% to .3% overall slope) with depressional areas not over 6" in depth. Smoothing is done with a land plane or similar equipment with a minimum of two passes in transverse directions. Surface field ditches generally of random pattern are used to pick up row drainage and drainage from depressional areas remaining after smoothing. Both single and "W" ditches are recommended to collect and dispose of excess row water. These are crossable ditches with an average depth of 12", flat bottom (2' min.) or "V" shape, 6:1 to 8:1 side slopes with spoil spread to permit free access of drainage water. Ditch spacing is variable depending on topography and soils with a maximum of 880 feet spacing recommended.

B. Recommended as a temporary practice on most bottomland soils to improve surface drainage until farmers can financially afford land grading or leveling or are sold on grading or leveling. Design criteria for bottom land is the same as for upland.

There are no particular problems on design criteria for land smoothing. However, selling it to farmers and getting quality construction and proper maintenance is a problem. Also a method of estimating benefits is a problem. The costs of land smoothing range from about $5.00 to $12.00 per acre.

Land Grading and Land Leveling. The two practices to date are considered by farmers and most SCS personnel in Missouri to be one and the same. Farmers that have planned and established these practices do so with the intent of irrigating when needed, however, their primary purpose at the time is drainage improvement.

The design criteria used is as follows:

Down slope - Minimum 0.1% - Maximum 0.3%
Cross slope - Minimum 0% - Maximum 0.6%
Lengths of runs - Maximum 880 ft. for fine textured soils to 330 ft. for the coarser textured soils.
Maximum cut 2.0 ft. depending on productive potential of soils at depth to be cut.
Construction tolerance is ± 0.10 ft. with no reverse grade permitted in the down slope direction.

The principal design problems are:

A. Lack of good information or research to arrive at benefits.

B. Construction of field ditches that are sufficiently dry during farming operations to permit crossing with farm equipment. This is a particular problem in the heavy clay soils.

C. Lack of firm guides or research data on spacing of field ditches or length of runs for row irrigation. (Field trials are in progress for determination of lengths of runs for furrow irrigation on several soil types.) Spacing of field ditches when surface drainage is the control is a problem. Field trials are not well adapted. Consideration should be given to obtaining this type information for different soils by research over a period of years.

D. Shrinkage factors to use for fills as well as for compaction caused by earth moving equipment over undisturbed areas is a problem that has to be dealt with by designers. This seems to be a determination that can be made only through experience. With the many variables involved, this problem probably is not one that can be solved by research.

The cost of land grading and leveling in Missouri ranges from $25 to $125 per acre with an average of approximately $45. Earthwork amounts to an average of 220 cu. yds. per acre.

DRAINAGE IN OKLAHOMA

by

Bill Burtschi[1/]

AREAS NEEDING DRAINAGE

The vast majority of the land needing drainage in Oklahoma is in the major river alluviums east of the 30-inch rainfall belt. On the Red River, all need is below Texhoma Lake. On the Arkansas, a few scattered jobs exist above Tulsa, but probably 95% of the drainage problems are downstream from Tulsa. The drainage problems on the Canadian Rivers and the Cimarron River are relatively few because of the soil texture. The Washita has spotted drainage problems.

The Verdigris River bottom in northeastern Oklahoma has been considered not feasible for drainage because of frequent overflows. With the completion of Oologah Dam in the near future, a large area will be added to the drainage need.

In summary, the great bulk of the drainage problems requiring group action by two or more farmers is in the Red River bottom below Lake Texhoma, the Arkansas River bottom below Tulsa, and the Verdigris River bottom below Oologah Dam. This area has a rainfall of 38 inches or more.

There will be very few projects without some hill land contributing area. It would be fair to estimate that the hill land area will be 25 to 50 percent of the total watershed.

ACCOMPLISHING THE TASK

Oklahoma has no public-financed channel improvement or levee projects. All drainage must be accomplished and paid for by the local landowners with any available ACP or 566 assistance. To date, no channel improvement 566 projects have been constructed. Pooling agreements have not been widely used.

LAND SMOOTHING HISTORY

Frankly, very little land grading or smoothing has been done in Oklahoma for better drainage. Most of the smoothing that has been done has been in connection with irrigation.

There has been, to our knowledge, some three or four 60-foot land planes and a few smaller size planes operated from time to time in drainage areas. They were used in an attempt to smooth the land without any prior work with hauling equipment.

1/ State Conservation Engineer, SCS, Stillwater, Oklahoma

There has not been much interest on the part of farmers for land smoothing. The experience in the past has been that land smoothing interest is coupled with an associated request for ACP cost-sharing. No cost-sharing has been allowed in Oklahoma.

DRAINAGE DESIGN CRITERIA USED

Design criteria for row lengths pretty much follows the same pattern throughout the state:

Soil Unit 3 - Very little drained. Row lengths about 300 - 400 feet.
Soil Unit 4 and 8 - Row lengths about 500-600 feet. Rarely over 600.
Soil Unit 9 - Usually random double field drains are used where needed.
No minimum row grades have been set. The rows are run in the direction of maximum slope insofar as practical. In the case of zero grade rows, double field drains are often used making 600 ft. rows to drain in both directions.

Since little or no land grading has been accomplished, no limits have been established for cuts and fills.

PROBLEMS

We have a need for row grade-length criteria to be used when planned in conjunction with land grading and land smoothing. Supposedly, there would be an increase in field drain spacing after grading and smoothing. Cost-benefit data is always welcome.

LAND FORMING IN TENNESSEE

by

Leon F. Silberberger[1/]

Interest in land grading and leveling is in the introductory stage in Tennessee.

In East Tennessee, the land grading practice is limited to the river bottom lands of the French Broad and Pigeon Rivers in Cocke County. A total of 388 acres have been completed to date. Surveys are underway for 875 acres in Monroe County at Tellico Plains on the bottom land of the Tellico River.

The work completed in East Tennessee has been on Congaree soils. Designs have been prepared for work on Staser, Hamblen, Sequatchie and Whitwell. These are loam, silty loam and fine sandy loam soils.

The main crops grown in the areas where land grading has been accomplished are truck crops. A small amount of this work has been completed on land being used for burley tobacco.

The land grading and leveling work in West Tennessee has been done in Lauderdale, Dyer and Lake Counties. Approximately 500 acres of land grading and 50 acres of land leveling has been completed

The limited amount of work accomplished in land grading and leveling operations has not been sufficient to indicate what the increased yields from these practices will ultimately provide.

A field of turnip greens in East Tennessee increased from 3.5 tons per acre to 11 tons per acre after the field was graded. Lauderdale County in West Tennessee reports an increase in yield of 250 pounds of lint cotton per acre and soybean crop yields are up due to the land grading operation.

Some decrease in yields have been noted in both East and West Tennessee, particularly in cut areas and in some fill areas due to compaction.

Gradients in grading work are being held to 0.5 percent maximum and 1.5 percent minimum. Length of grades has been set at 1000 feet for maximum grade and 300 feet for minimum grades.

We believe that land grading has a future in our conservation program in East and West Tennessee. Land leveling will be particularly needed in the delta area of West Tennessee.

1/ State Conservation Engineer, SCS, Nashville, Tennessee

LAND GRADING

C-11. Shaping or land grading to permit effective surface drainage

CONDITIONS

This practice is applicable only on land which is suitable for, is now in, and is intended to remain in row, grain and hay crops, and where:

1. Ridges, pockets or channels can not be removed by normal farming operations.

2. Land is of the capability to justify grading for drainage.

SPECIFICATIONS

1. Design - Normally, a grid map of the area to be graded will be required to locate ditches and to balance cuts and fills.

2. Excavation - A soils survey of the area to be graded will be made to determine the maximum cuts that can be made.

3. Gradients

a. Maximum allowable gradients:

(1) Fine textured soils - 0.5 percent.
(2) Sandy soils - 0.5 percent.

b. Minimum gradient - 0.15 percent.

c. Grades may be uniform or variable.

d. Reverse grades are not permissible.

e. Length of grade:

(1) At maximum grade - 1000 feet.
(2) At minimum grade - 300 feet.

4. Ditches:

a. Capacity - The design capacity shall be such as to remove the excess flow from the watershed before damage to crop occurs. For improved pasture, the removal of 1 inch in 24 hours will be generally satisfactory. For most cultivated crops, the removal of 3 inches in 24 hours will be required. For high value or water-sensitive crops, a higher rate of removal may be required. (Tables in Part 7 of the Farm Planners Engineering Handbook show ditch capacities.)

b. Velocity - Velocity shall not exceed 3.0 feet per second for unvegetated ditches nor exceed 5.0 feet per second for vegetated ditches.

c. Alignment - The alignment of a new ditch shall conform to the natural drainage pattern of the land as nearly as practical.

d. Outlet End - Lateral water may be lowered into a ditch by excavating the lateral on a level grade from the bottom of the ditch for a distance of 100 to 300 feet, depending on the size of the lateral, and thence on a non-erodable grade to the point of intersection with the normal grade of the lateral, or by the use of a metal pipe of sufficient capacity, supported on the outlet and, if necessary, and extended to discharge water from the pipe into water in the outlet.

e. Outlets - The outlet shall have sufficient capacity to take care of the designed outflow of the new ditch without dams to the area adjacent to the outlet.

5. Permanent Structures - Design and specifications for permanent structures will be prepared by engineering specialist of Soil Conservation Service.

6. Additional Specifications - Specifications shown in TN-ACP-61 specifications for Practice C-9, Open Farm Drainage Ditches (A) Trapezoidal Ditches, (B) V-Ditches and (C) W-Ditches will apply where these types of ditches are used.

LAND LEVELING

TN-ACP-61
Special Practice

C-13. Leveling land for more efficient use of irrigation water and to prevent erosion.

CONDITIONS

1. Soils must have sufficient depth to permit the required grading and still leave a zone suitable in depth and quality for normal plant root development.

2. Slope of field must not exceed two percent.

3. Sufficient water must be available to provide, at least, ten gallons per minute per acre irrigated.

SPECIFICATIONS

1. Site Eligibility - A soil survey of the area to be leveled will be made to determine the practicability and feasibility of leveling. The soils in the area shall have intake rates, available water-holding capacities and other physical characteristics that will permit efficient application of water by the irrigation method selected.

   The soils in the area to be leveled shall be capable of producing relatively high yields of the crop or crops to be irrigated and shall have sufficient depth to permit the intended leveling without permanent impairment of their productive capacities.

2. Design Criteria - A grid-type topographic survey of the area shall be made and the grid corners staked at intervals no greater than 100 ft. x 100 ft. All crop residue shall be removed (or turned under and allowed to decay) and all crop ridges and similar surface irregularities shall be eliminated by disking, harrowing or planing before the area is staked.

   Using the soil survey and the topographic survey as bases, a leveling plan shall be prepared. The leveling plan shall indicate the slopes (in both directions) to which the area is to be leveled and shall show the required depth of cut or fill at each grid corner. The plan shall also include and show the location, dimensions, and elevations of all ditches, irrigation pipelines (other than portable), structures and other appurtenances required to convey water to the furrows or borders and to provide facilities for adequate drainage.

   The slopes to which the area is to be leveled will depend upon the method of water application to be used and the crop or crops to be irrigated but, in any event, they shall fall within the permissible ranges set forth in the following table.

Permissible Slope Ranges for Leveled Land

Irrigation Method	Irrigation Slope Feet per 100 Feet	Cross Slope
Furrows Row Crops	0.30 maximum 0.05 minimum	Shall not exceed irrigation slope
Graded Borders Alfalfa-Small Grain Annual Hay	1.00 maximum 0.10 minimum	0.10 ft. per border maximum
Graded Borders Permanent Sod	2.00 maximum 0.10 minimum	0.10 ft. per border maximum
Furrows and Borders Rotated Crops	0.30 maximum 0.05 minimum	0.10 ft. per border maximum

An estimate of the quantities of cut and fill yardage required to complete the job shall be prepared and will accompany the leveling plan. In addition to the quantities required to complete leveling operations, all quantities required for the construction of ditches and levees shall be included in the estimate. The quantities of cut and fill yardage must be in reasonable balance after appropriate allowances are made for settlement and shrinkage.

3. Construction Specifications - Leveling operations shall not be conducted when the moisture content of the soil is sufficiently high as to result in excessive soil compaction.

Land leveling operations shall be performed by the use of tractor-drawn loading-type scrapers or similar equipment deemed suitable by the engineer.

Grade stakes shall be left undisturbed until all grading operations are complete, at which time, the completed grades, ditch sizes, and the installation of pipe lines, structures and other appurtenances shall be checked for compliance with the leveling plan by the engineer.

The completed grades shall be within 0.10 foot, plus or minus, of the grades shown on the plan at each grid corner and at all other points where measurements are taken by the engineer. In addition, there shall be no reverse grades in the direction of irrigation, and there shall be no low places or pockets from which water will not drain.

All deviations from the planned grades as staked in the area shall be corrected before the grading equipment is removed from the site.

After grading operations have been completed in a satisfactory manner, the surface of the field shall be planed with no less than three passes of a land plane (or other equipment deemed suitable by the engineer). The first two passes of the plane shall be made diagonally with respect to the grid corners shown on the plan and at approximate right angles to each other. The final pass shall be made in the direction of irrigation as shown on the plan.

LAND GRADING AND LAND SMOOTHING FOR DRAINAGE IN TEXAS

by

N. M. Faulk[1/]

The Soil Conservation Service made a drainage survey report in 1960 for the United States Study Commission - Texas. The purpose of this survey report was to locate and inventory acreages by land uses, having drainage, or wetland problems. From this report, it was determined that there are approximately 6,900,000 acres feasible for drainage. Adequate drainage systems have been installed on 420,000 acres, or 6.1 percent. Of the area feasible for drainage that has not been drained, it is estimated that 3,300,000 acres are in cropland, 2,000,000 acres in pasture, and 1,180,000 acres in woodland.

The above figures include 560,000 acres in the Rio Grande Plains Land Resource Area, which differs from the remainder of the drainage problem area in the State, because of intensive irrigation, low rainfall (20 - 35 inches) and both surface and subsurface drainage problems. The remainder of the problem area is made up of the Coast Prairie, Coast Marsh, East Texas Timberlands, Blackland Prairies, and Bottomlands Land Resource Areas. The rainfall in the above listed land resource areas ranges from approximately 35 inches in the western extremity to nearly 60 inches in the eastern edge of the problem areas.

The Coast Prairie Land Resource Area occurs along the Gulf Coast of Texas. Natural drainage is deficient because of flat terrain and very slowly permeable subsoils. The crops grown are primarily rice and general crops such as cotton, corn and grain sorghums. There are approximately 420,000 acres of rice irrigation annually with over one and one-half million acres in a rice-pasture rotation. The Coast Marsh lies between the Coast Prairie and the Gulf of Mexico and is not feasible for drainage.

The East Texas Timberlands Land Resource Area lies along the eastern side of the State and north of the Coast Prairie. Drainage needs are relatively minor and occur for the most part along the southern edge of this resource area in a broad area of nearly level to gently undulating lands called "Flatwoods". Most of this area is in timberland with scattered areas of pasture and general cropland.

The Blackland Prairies occur in a fairly wide belt in east central Texas. Drainage problems are usually minor, affecting small isolated areas of pasture and general crops such as cotton, corn and grain sorghum.

1/ Drainage Engineer, SCS, Ft. Worth, Texas

Bottomlands Land Resource Area consists of soils occurring mainly along major streams such as the Brazos River, Trinity River and Red River. These streams and drainage problem areas are located in the eastern one-third of the State. The major crops in this area are cotton, corn, grain sorghum, alfalfa and small grains. These river bottom areas make up over 50% of the drainage problem area in Texas.

It can be seen from the above report on land resource areas that the main surface drainage problem in Texas is along the Gulf Coast in the Coast Prairie Land Resource Area and up the major river bottoms in the Bottomlands Land Resource Areas.

Land grading, land smoothing and land leveling are practices which occur and are needed throughout the drainage problem area of Texas. All three of these practices appear on the SCS Annual Progress Report but figur on land grading are incomplete and will be included as part of the land smoothing figure. As of June 30, 1960, there were 428,553 acres of land smoothing on the land within the drainage problem area. Eighty percent of this practice was concentrated in the rice irrigation section of the Coast Prairie Land Resource Area. The remainder was scattered throughout the Bottomlands Land Resource Area. As of June 30, 1960, 53,921 acres of land leveling had been applied in the Coast Prairie and Bottomlands Land Resourc Area within the drainage problem area. Approximately 80% of this land leveling is in the Brazos River bottom. The Lower Rio Grande Valley, which is also in the drainage problem area, had applied 202,260 acres of land leveling as of June 30, 1960.

In Texas, the purpose of Land Smoothing is to eliminate surface irregularities of rice land or non-irrigated lands needing surface drainage in such a manner as to: (1) provide more effective surface drainage, (2) hold erosion damage to a minimum and (3) facilitate water and soil management. The purpose of Land Grading is to alter the topography of land which are so flat and where undulations are such that precision grading is needed to provide desired drainage. The purpose of Land Leveling is to alter the topography of irrigated land or non-irrigated land in such a manner as to obtain efficient use of irrigation water and/or to make efficient use of rainfall, hold erosion damage to a minimum, and facilitate water, plant and soil management.

For detail specifications on these practices, it will be necessary to refer to Conservation Practices TX-7 Land Leveling, TX-13 Land Smoothing an TX-18 Land Grading. Generally, the finished grade for land grading and land leveling should not exceed 0.3 percent and must not exceed 0.5 percent For land smoothing, the overall land grade after smoothing should not excee 0.6 percent. Generally, there are no minimum grades except where reference is made to water ponding, etc. The maximum depth of cut on any land formin practice should not exceed that which would permanently limit normal crop production. Another guide on cut depths is to not exceed one-half the dept of topsoil unless the cut areas are treated to restore productivity. The summation method of computing volumes of earth work is used on both land grading and land leveling projects.

During 1960, drainage guides were developed and approved for the Texas drainage problem areas. The drainage guides were broadly grouped, first by rainfall area and drainage coefficients for removal of excess rainfall, and further grouped by land resource areas. The final grouping was by soil name and symbol according to permeability and land slope. Under each soil grouping, the recommended specifications were given by land use for each type or kind of drain such as surface field ditches, quarter drains and laterals. The range of land use under each soil grouping might include general crops, tame pasture, range or cropland (rice-pasture). There are three separate drainage guides developed for Texas and each guide has 10 to 15 soil groupings with recommended drainage specifications under each grouping so it would not be practical to list them all here. However, the following comparative example is fairly representative. The recommended spacing for surface field ditches for a Lake Charles Clay or Bernard Clay loam 2al for general crops is 400 to 800 feet in the East Coast Prairie guide and 600 to 1000 feet in the West Coast Prairie guide. The lateral spacings or length of surface field ditches recommended are 1000 to 1400 feet in the eastern half and 1000 to 1600 feet in the western half of the Coast Prairie problem area. Surface field ditches serving areas in excess of 25 acres in the east should be checked for capacity and in the western half this figure was raised to 30 acres. The range of spacings is for normal conditions. The wider spacings are used for naturally smooth topography or on fields which have been graded, smoothed or leveled. Prior to the development of the present drainage guides, the recommended spacing on this type of soil was 400-600 feet for surface field ditches with maximum lengths of 1000-1200 feet regardless of location or smoothness and uniformity of the land slope.

Surface field ditches on graded fields are arranged at right angles to the direction of steepest slope, the maximum spacings are specified in the drainage guide, and this spacing is varied to fit with low areas where excessive earth volume would be required to continue the slope up to maximum lengths. Surface field ditches on land smoothed fields are located in depressed areas, at right angles to steepest slopes and within the spacing range in the drainage guide. Land leveling is installed on a field primarily for more efficient surface irrigation; however, in some cases, improved drainage may be the initial objective. The drainage system installed on the leveled fields is in accordance with the drainage guides and is laid out in a uniform regular pattern with "squared up" fields.

Construction tolerances for the land smoothing practice are as follows: (1) ponded areas of more than 0.1 foot are not allowed, (2) mounds and ridges should not exceed 0.1 foot above the finished grade, (3) small and isolated areas of slightly greater land slope than 0.6 foot may be included in the smoothed area to permit proper utilization. Construction tolerances for land grading and land leveling are as follows: (1) cut and fills are shown to the nearest .05 foot, (2) fields are checked for the planned grade rather than elevations and variations from the planned grade should not exceed plus or minus 0.1 of a foot.

It can be seen from the foregoing report considerable progress has been made in the solution of the drainage and land forming problems in Texas. However, if continued improvement and advancement are to be made, several problems and questions must be solved.

(A) Research is needed relative to the maximum length of rows and the degree of drainage required considering soil, topography, and management. Limited field studies which have been made indicate some variation from the recommendations in the current drainage guides. On smooth uniform slopes, equal to those usually obtained by land grading, greater row lengths are indicated.

(B) For land forming practices

(1) What should be the minimum slope requirements in the 45 to 50 inch rainfall area on Coast Prairie and Bottomland soils? At the present time, a grade of .05 feet per hundred is generally considered to be the minimum; however, there are some areas where 0.1 foot and greater slope is used as the minimum.

(2) Should the land slopes vary with clay soils, fine sandy loams, etc.?

(C) A continuous and uniform slope is planned and constructed with the land leveling practice. For irrigation purposes, the uniformity of the slope is considered important enough to justify the extra cost involved. What would be the extra value of the uniform slope in a drainage system?

(D) Water leveling, as an efficient means of land forming, has recently been introduced on the Rice Experiment Station, Crowley, Louisiana. A number of farmers in Louisiana, the Beaumont Experiment Station, Texas, and one farmer near Edna, Texas have successfully used this method of land forming. There are questions concerning this practice which will need to be answered.

(1) What effect will the minimum to level grades left after water leveling have on the drainage of the fields involved?

(2) What effect would water leveling have on the soil structure of Coast Prairie and Bottomlands soils found in Texas?

(E) Additional research information is needed concerning the effects of drainage and land forming practices on both the quantity and quality of rice production.

LAND FORMING IN THE SOUTHEAST

by

E. A. Schlaudt[1/]

This discussion is based on the definitions for land grading and land smoothing being those given in the Soil Conservation **Service's National** Catalog of Practices, dated 1959. It is, of course, further based on these practices as used only for improvement of surface drainage. "Land grading" used here means a precise sloping of the surface but not to "land leveling specifications".

Average annual precipitation for the Southeastern Region will average about 50 inches with some 30 to 40 inches of this total falling during the growing season, i.e., from March to November. This will illustrate the need for surface drainage during the crop season.

The soils with more nearly level topography vary in texture from deep fine sands to clays. If I should choose to describe our predominant wet soil classifications, it would have to be "ML" or "SL". My discussion today will not include Delta soils, protected by levees in Mississippi. Mr. Tisdale included the Delta soils in his discussion. It is my opinion now that very little land forming, except for land smoothing, will ever be done on alluvial soils which are subject to major flooding.

The crops grown on the flat, wet soils in the Southeast include citrus, rice, soybeans, corn, pasture, cotton, truck, and flue-cured tobacco. Land forming will very probably be done, sometime, for most of these crops. In some instances it will consist of land leveling for irrigation but this also accomplishes a suitable surface drainage job. It might be brought out here that the land forming job for these various crops may consist of land grading, land smoothing, land leveling or land bedding. The latter is very important on almost level fields of fine-textured, slowly permeable soils.

The type of land forming selected for any individual field will depend on (a) the depth of the surface horizon; (b) the crop to be grown; (c) the allied need for subsurface drainage; and (d) the use of sub-or surface irrigation. Example: A soil of adequate surface depth with a seasonal high water table would need (a) for corn or grass--simple land smoothing; (b) for truck--land smoothing or grading and subsurface drainage; (c) for citrus--deep sub-surface drainage and bedding.

The predominant need for land forming is in the low, relatively flat and mostly sandy Atlantic and Gulf Coastal Plains. To date, this has been limited almost entirely to land growing truck, citrus and pasture. To our knowledge no lands have been graded but smoothing has been done quite extensively. A small amount of land leveling and some bedding has been completed. I would estimate that we have some nine million acres of land forming on open land to do in the Southeast but which will consist mostly of land smoothing. If good, wet timber land is cleared, this figure could be tripled.

1/ Drainage Engineer, SCS, E & WP, Spartanburg, S.C.

Land bedding - This practice is now used for citrus, for pasture, and to a limited extent, for flue-cured tobacco.

Beds for citrus have been used for both surface and subsurface drainage. We are now recommending the use of deep drains, open or closed, in combination with low beds for surface drainage.

Single or double-row beds are being used in South Georgia on flue-cured tobacco fields. They are primarily for increasing the distance between the surface and the water table. This, in effect, attempts to make them do the work of subsurface drains. We are now recommending closed drains and normal surface culture for tobacco.

Some bedding is done in all states for better surface drainage in pasture lands. We recommend this primarily for the nearly level and fine-textured, slowly permeable soils in the lower coastal plain. It is for these conditions that most bedding in the Southeast will be done. We do not include the normal, annually prepared beds, used mostly for certain truck crops, in our bedding classification.

Land smoothing - This practice will possibly be used more in the future than all the other land-forming practices. It is well adapted to sandy soils with high water tables. It is widely used for truck and pasture lands. One important area of use will very likely be in the subirrigated pastures in South Florida. It is also, as we see it now, the only land-forming practice that can be economically maintained on overflow lands. Land smoothing will be widely recommended in the Southeast because it requires no detailed surveys, is economically done, and is adequate for most of our surface water problems.

Land grading - This is a precise practice which will find maximum application on the intensively used and slowly permeable soils in the Southeast. As stated previously, we have no record of any grading having been done in the Southeast. No specifications have as yet been prepared for grading. Such specifications will, I would think, be most tolerant in requirements for row length, grade changes along the length of the row and in cross slope. We believe that our specifications will probably tolerate long rows for all soils with row gradients being restricted on the sandy soils. Research is needed to determine this. No effort will be made to limit cross slope by moving soil, although cross slope could well be a factor in planning the renovation of the field surface. Land grading is the practice for which research and field observations will be required. Many observations can be appropriately made on surfaces where land leveling has been done and we propose to utilize this procedure in getting up our land grading specifications.

LAND SMOOTHING AND GRADING FOR DRAINAGE
IN THE CORNBELT AREA

by

Guy B. Fasken[1]

Over 50 million acres of tight soils in the states comprising this area are in need of adequate surface drainage.[2] Included in the lands needing surface drainage are the red plastic soils of northern Wisconsin and Michigan, the Paulding-Nappanee soils of northeastern Indiana and Ohio, the Clarence and Swygert plastic tills in northern Illinois, the heavy clays of the Red River Valley in Minnesota, the Alamena-Spencer soils in Wisconsin and the large claypan areas of Missouri, southern Iowa, southern Illinois, Indiana and Ohio. These soils have slow permeability and their surface is usually covered with innumerable small depressions so that surface ditches in these soils do not provide the land with adequate drainage. The land must be shaped so that the excess surface water will reach the surface ditches installed. Good subsurface drainage could not be expected if only the main tile line is installed; neither can good surface drainage be expected without land smoothing.

Land smoothing and grading practices are not confined to the tight soils but should be used on land that is tiled. The removal of excess water by surface drainage practices reduces the volume of water to be handled by the tile, and, probably more important, the soil starts drying earlier. A well planned subsurface drainage system should include provisions for surface water removal.

Surface drainage has been considered as a practice to be used on flat lands. The value of surface drainage to steeper lands is now being recognized. Smoothing of the land surfaces between terraces and cross slope ditches has been found to be advantageous for erosion control, farming operations, and crop production. Therefore, to the 50 million acres must be added many million more acres of sloping land and tiled land to which land smoothing and grading practices will prove beneficial.

In the fiscal year 1960, the Cornbelt reported 33,174 acres of land graded and smoothed, and the installation of 1,878 miles of surface ditches. These figures represent 11.5 percent of the smoothing and grading, and 34 percent of the surface ditches constructed in the nation. Several of the states in the Cornbelt anticipate that there will be some increase in the use of the practices.

Land smoothing is a tillage operation in the Cornbelt and the figures reported above do not represent the total use of this practice. The figures represent the amount of land where the practices have been used for the first time.

1/ Drainage Engineer, Engineering and Watershed Planning Unit, SCS, Milwaukee 3, Wisconsin

2/ From paper, "Surface Drainage of Tight Soils in the Midwest" by Keith H. Beauchamp.

ACP payments for land smoothing and grading are made in several states. The payment usually made is 50 percent of the cost. At least two states make no payments for the practices.

Land grading and smoothing are operations discussed under the headings of "land forming" - "land preparation" or "land shaping" -- depending upon the locality. Land smoothing is the removing of irregularities of the land surface and is the practice mostly used in the Cornbelt. Land grading is the changing of the surface of the land to improve both drainage and irrigation. If the grade involved in land forming is constant for a length determined by the permeability of the soil for the purpose of irrigation, it is called "land leveling". If the grade involved in land forming varies, and the length of the run is controlled by drainage requirements, the operation is "land grading for drainage". Frequently, in the Cornbelt, the operations provide or can provide for both drainage and irrigation. For this reason the correct name for the operation is sometimes difficult to determine. Land graded and smoothed for drainage may eventually be irrigated. This is true on the river bottom lands in Missouri and Iowa.

Numerous problems are involved in extending the use of these practices. The non-technical problems include the following:

1. An educational program is needed for not only the farmer but for all the persons who will be involved. The result should be an enthusiasm for the work.

2. Lack of proper machinery and experienced operators limits the operations.

3. Engineering time requirements limit the land grading practice to the technical time available.

4. Installation time for the practices is usually limited to the time between crops.

Technical information is also needed to improve our design and understanding of the practices. Criteria should be established to fit local needs and guide lines must be provided. Information on the following questions will assist in setting up the guide lines:

1. What are the lengths of rows or slopes required for the various soil groups?

2. Do these practices permit the increase of surface ditch spacing over areas not smoothed or graded?

3. What grades are applicable to the various soil groups?

4. What effect do these practices have on soil compaction?

5. Should the depth of cut be limited? If so, what are the limits for the various soil types?

6. What is the method, cost and time involved to restore the exposed subsoil to an economic level of production?

7. There is need for cost data for these operations--both engineering and construction costs.

8. What are the benefits derived from the installation of these practices? Elimination of "trouble spots" is some reward but the increase in production will be the major consideration.

9. Compilation and evaluation of research work done on these practices would be helpful if distributed.

The need for land smoothing is determined from observation and through interview with the farmer involved. The criteria for smoothing varies from two to three passes of the land plane with the direction of the passes specified. These were considered the minimum number of passes required and so the minimum becomes the standard for all fields regardless of condition. Water disposal systems are required and, in case of parallel ditches, the spacing is usually given and also the minimum depth and grade.

Land grading criteria has been set up in states using this practice in conjunction with irrigation. These criteria follow closely the requirements for irrigation. Surface ditches are recommended with spacing and grade requirements given. The allowable depth and extent of deep cuts on a field are specified.

With the increasing use of these practices, criteria for both practices should be developed to be as uniform as possible.

Monetary benefits derived from the use of these practices are not available. The general belief is that they are profitable and should have wider use. In many cases of good management, practices cannot be used to the fullest extent unless smoothing and grading have been done.

The attached map shows the area of distribution for one type of land leveler. The cross-hatched area indicates a greater concentration of the machines. A large number of the machines are used for a land preparation tool and a large number are privately-owned and not used for custom work. Assuming that the machines were all used, our annual report would indicate that 120 acres of land were leveled per machine. If this is a representative amount of work to anticipate future accomplishments, many of us will not see the day of completion.

LAND GRADING AND SMOOTHING IN THE NORTHEAST

by

Elmer W. Gain[1]

There are two to three million acres of flat to nearly flat farmlands in the Northeast comprised chiefly of heavy textured surface soils which could benefit by surface grading and smoothing. Most extensive areas are located on the lake plains and river flood plains of northern and northwestern New York and Vermont, coastal flats of southern Maine and New Hampshire, and the coastal plains of New Jersey, Delaware, Maryland and Virginia. Numerous small areas are scattered throughout the region, chiefly on river bottom land.

More precise grading and smoothing of land surfaces has been underway in the Northeast for only 5 or 6 years. To date, less than 10,000 acres have been improved under SCS supervision, and most of this has been on hay and grassland in Vermont and Maine with a start made this year in New York. Some research has been undertaken by ARS and Virginia Polytechnic Institute staff in Virginia, and a small project has been recently established by Cornell University with SCS cooperation in Jefferson County, New York. Several installations in New Jersey and Maryland have had for their primary purpose the establishment of smooth uniform surfaces for the mechanical harvesting of high value crops, such as peas, spinach, etc. Substantial reductions in damage and loss of the harvest crop and breakdown in equipment are obtained on such surfaces.

Land grading is not entirely new in the Northeast. Crowning of lands between shallow surface ditches constructed to a planned grade has been carried on by SCS technicians for more than 15 years as part of an overall surface water disposal system which must often include interception and diversion of upland water. The surface drainage is developed similar to the centuries-old European practice of land bedding. Approximately parabolic surfaces are shaped from ditch spoil across the intervening lands by means of scrapers, blades and bulldozers. Additional fill when needed is obtained from the ditch shoulders by flattening side slopes. Crown heights between centers of bed and ditch bottom are adjusted to widths of the crowned land and ranges from 14 inches on 30 to 45 feet widths to 24 inches for 85 to 100 feet widths. Drainage of wider beds on heavy soils have been less effective. Some smoothing by land plane may permit considerably wider bed widths, and trials to establish such increased widths for grasslands in the colder northern parts of the region are needed.

The narrow margin of financial returns obtained from hay-pasture crops in the New York-New England area does not permit unlimited expenditures for surface grading. Thus, development of graded random ditches with warped land surfaces smoothed to provide free flow toward such ditches has been favored in areas where the surface is slightly undulated. Usually, half to two-thirds less cut yardage is required and less follow-up in removing subsidence pockets. Short and often wet growing seasons occuring during construction season hamper and restrict grading work. Long rotations of

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5 to 6 years for hay and forage crops and frequent small and isolated acreages discourages private ownership of land planes. However, results thus far show that in combination with proper agronomic practices, hay yields have been increased from an average 1/2 ton per acre before improvement to 2 and 3 tons per acre. Also, winterkill of legumes, such as alfalfa, through crusting of snow and ice sheets, has been drastically reduced, so that loss of alfalfa during several severe winters has been reduced from 90 percent in ungraded fields to 10 percent in improved fields.

Planned minimum grades and lengths of slopes for graded surfaces other than on bedding systems have been guided by experience in the Cornbelt States. Observations seem to indicate better drainage is obtained when surface grades are maintained upwards of 1/4 percent for slope lengths over 400 to 500 feet.

Specific investigations and studies are needed for the climate and cropping conditions encountered in the northern part of the Northeast to determine the effect of slope and permissible length of overland water travel on smooth vegetated surfaces as well as plow furrows and crop rows. Better knowledge is needed on yield differences, installation costs, and amount and duration of yield depression caused by exposed soil surfaces. The generally thin cover of surface soils in the Northeast has made most agriculturalists sensitive to subsoil exposure and has been a major deterrent in the expansion of land grading and smoothing on heavy soils of the Maryland-Delaware coastal plain.

Better guidelines are needed for estimating shrinkage of various textured soils placed in shallow fills by light graders and land planes, and tolerances to be used for meeting grades by machine operations. Amounts of overcuts used in design to assure ample allowance for shrinkage and fill appear to be unrealistic.

LAND LEVELING PROGRESS AND
OTHER IRRIGATION PROBLEMS IN THE SOUTHERN PLAINS

by

Leon Lyles[1]

Land forming originated for the purpose of surface water management whether for drainage, irrigation, or moisture conservation. The purpose is generally dictated by prevailing soil and climatic conditions and water supply. Major portions of the Southern plains are characterized by low annual rainfall and high summer temperatures. Therefore, the primary purpose of land leveling in this area is for more efficient use of irrigation water with a budding interest in leveling for moisture conservation.

Some caution is needed in using the term "land leveling". The term usually means leveling the surface profile to a constant slope or grade in one or more directions as opposed to the literal meaning; to make perfectly flat or horizontal. However, some land is leveled as close to the literal meaning (zero slope) as precision of present earth-moving equipment and workmanship will permit.

The application progress in land leveling for irrigation in the states of Kansas, Oklahoma, Texas, and New Mexico is shown in table 1. Since 1946 the number of acres leveled in these states has increased 20 times (61,281 to 1,229,238). Texas showed large increases during 1956 and 1957. This appears rather impressive. However, in Texas the number of acres leveled for irrigation as reported by the Soil Conservation Service represents about 13 percent of the total irrigated acreage.

Layout and Performance

Field Leveling - For land units with relatively flat slopes that allow leveling to a single plane without making major cuts. Texas SCS specifications permit grades of 0.5 percent in the direction of water flow, with side slopes of 0.1 percent for furrow type irrigation. Problems: Do not have positive water control, tend to overwater at both extremities.

Bench Leveling - Parallel or Contour. For steeper slopes that cannot be leveled as one plane. Specifications are 0.05 percent in direction of water flow and not more than 0.1 foot fall across bench. Problems: Loss of land in escarpments which harbor rodents and create weed problems. Where high water tables exist, water logging occurs at the base of each succeeding bench.

Nonirrigated Field or Bench Leveling and "level" irrigation - Grades are not to exceed 0.05 percent in direction of rows or tillage with cross row grades not to exceed 0.1 percent. Problems: unless bench leveling is used, slopes of one percent may require deep cuts and expose subsoils that may be low in productivity for several years.

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Table 1. Growth of land leveling in the Southern Plains, acres*

Year	Kansas	Oklahoma	Texas	New Mexico
Cumulative to 1952	56,685	34,706	263,495	117,428
1953	11,513	11,689	50,853	22,273
1954	13,592	7,506	36,986	20,080
1955	23,486	- - -	57,973	23,279
1956	32,258	8,066	140,192	19,852
1957	28,280	5,976	100,680	16,920
to June 30, 1959	16,222	6,413	84,672	15,663
Total				
June 30, 1959	182,036	71,856	734,851	235,495
Jan. 1, 1946	8,404	1,390	37,528	13,959

* Taken from Agricultural Statistics for the years indicated, and represents the assistance given by the SCS.

Drainage problems exist in most arid or semiarid irrigated areas. This is especially true for the Pecos and Mesilla Valleys of New Mexico, and the Rio Grande Valley and Coastal Plain of Texas (2). Their solution usually requires subsurface drainage with deep open ditches, tile lines, wells or a combination thereof. However, precision land forming that would allow a more positive control of water applied could ease the drainage problem arising from high water tables. Yet there remains the conflicting need of percolating water for maintaining a favorable salt status in the soil.

Land forming for level irrigation appears to meet many of the requirements for efficient water management. According to Ross (4) the use of level irrigation systems for general field crops was introduced in the Southwest during the period 1942-1947 by the Soil Conservation Service. He enumerates the merits of level irrigation as (1) high application and distribution efficiencies, (2) reduced labor costs, (3) maximum utilization of rainfall and reduced erosion, and (4) leaching for salinity control. Level irrigation systems are characterized by slopes of 0.05 percent or less in the direction of water flow. This compares to maximum permissible slopes 10 times greater for SCS field leveling specifications in Texas. By 1959 level irrigation systems had been installed on 175,000 acres in the Lower Rio Grande Valley of Texas.

Land leveling progress for moisture conservation has been very well summarized by Robins (3). Present efforts include (1) level terraces (2) conservation benches where contour level benches with intervening contributing areas are established and all runoff from a fixed contributing area is impounded on the level bench, (3) utilization of opportune runoff by diverting water collected in small drainage channels onto adjacent leveled land, and (4) land leveling on nonirrigated cropland to retain and uniformly distribute intense precipitation which would otherwise run off. Leveling nonirrigated land eliminates the need for drainage by removing depressional areas that collect water. All the practices have occasional drainage requirements, but are completely overshadowed by the need for controlling and using water that would run off. The physical and economic applicability of the methods have not been established with quantitative information.

Other Irrigation Problems

A major irrigation problem in parts of the Southern Plains is how to effectively manage a limited or dwindling water supply. For example, in the high plains of Texas containing 3 1/2 million irrigated acres the underground water level has dropped from an average of about 5 feet in 1951 to 43 feet in 1958 (1).

Seepage or conveyance losses continue to create subsurface drainage and salinity problems where these losses contribute to an existing high water table.

Although additional needs have been stated, current research efforts in the Southern Plains with limited personnel are mainly directed toward irrigation timing, rates of application, and water requirements of crops. Research on surface application systems, methods and design criteria for applying irrigation water, are carried on in other areas.

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LAND LEVELING PROGRESS AND OTHER IRRIGATION PROBLEMS IN WESTERN IRRIGATED AREAS

by

Dean C. Muckel[1/]

Land leveling for irrigation in the semiarid West has long been standard practice. Almost from the start of irrigation there was some form of land shaping or smoothing so as to obtain a better water distribution. Admittedly early work was crude but the need for land leveling was quite apparent, particularly to those trying to work the water over the land, so as to wet high places and prevent accumulations in low spots. "Land leveling" in irrigation means grading or smoothing the land surface to a uniform grade. In the West design criteria is based on irrigation water application as related to soils, length of run, etc., with no provisions to provide surface drainage as may be required under rainfall conditions. In other words we design and prepare our land for a controlled amount of water.

Land leveling progress in the 17 Western States is indicated in table 1 which shows the area leveled for most efficient use of irrigation water for the period 1936-59 and for the year 1959. Probably the most striking item in this table is the "Portion of State Total Assistance" devoted to land leveling. In the far West, the arid State of Nevada shows approximately 36 percent of all money spent under the Agricultural Conservation Program was for land leveling; Idaho was not far behind with 27 percent.

Our aim is to get the most out of a limited supply of irrigation water. This means a uniform application of water over the field.

While land leveling has been practiced for many years, research studies on soil-moisture distribution under various irrigation practices, land slopes, soils and rate of irrigation water applied, clearly indicate merely leveling to a uniform grade is not the only answer to efficient irrigation.

The present trend is the reduction of slope, and there are those who are convinced that "dead level" is the proper landforming procedure, although most technicians agree that some slope is usually desirable. Soils with low intake rates are more adapted to "dead level" irrigation than those having high intake rates. Bench leveling is coming more and more into the picture in the irrigated West. It permits more efficient use of both rainfall and irrigation water and requires less labor for irrigation. In those irrigated areas subject to intensive rainfall, bench leveling provides a valuable means of reducing slope and thereby reducing erosion. It also permits uniform distribution of surface water and resulting addition to the soil moisture.

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Table 1. Area of land leveled for irrigation during the period 1936-59 and the year 1959, and the portion of State total assistance under the Agricultural Conservation Program.

State	1936-59	1959	
	Area	Area	Portion of State Total Assistance
	Acres	Acres	Percent
Arizona	435,405	15,325	19.3
California	863,933	55,850	11.1
Nevada	138,315	6,603	35.7
Utah	260,916	15,554	21.8
Idaho	507,724	25,981	27.0
Oregon	341,418	12,194	12.8
Washington	195,010	10,575	7.8
Kansas	171,313	14,577	3.6
Oklahoma	30,528	3,228	.8
Texas	1,040,599	63,643	3.8
New Mexico	288,944	9,285	9.8
Montana	175,751	11,941	11.4
Wyoming	190,118	6,500	12.6
Colorado	712,760	21,042	14.9
Nebraska	385,137	15,372	4.2
South Dakota	22,490	1,590	1.0
North Dakota	5,107	571	.4

There are however certain problems involved. For instance, at the Scotts Bluff Experiment Station in Nebraska, approximately 30 acres of land with a natural slope of 3 to 6 percent were bench leveled for experimental purposes. The overall width of the benches is 52 feet on the gentle slopes and 54 feet on the steeper slopes. The basins, or cropped area, are 44 feet wide which allows 8 to 10 feet of width for the bench ridges and escarpments. Bench ridges were planned on the basis of an 8-inch height above the basin, a crown width of 12 inches, and 2 to 1 side slopes for escarpments.

The first item which attracts attention is that about 20 percent of the total area is taken up by the ridges and is a noncrop area.

The basins were constructed level ±0.1 foot, but settlement in some of the deeper fills caused a few places to be as much as 0.3 foot low. This is not uncommon and a releveling or smoothing operation is required after the first irrigation season. Settlement or minor uneveness poses more of a problem under "dead level" benches than where some slope is provided.

The irrigated benches at Scotts Bluff have been operated for 3 years. One of the main difficulties experienced in farming was the high edges of the basins which prevented the outside one or two rows from receiving adequate irrigation as well as causing a poor job of planting, cultivating, and harvesting in some instances. This condition at the edges of the basins has been difficult to avoid as it is caused by a number of different operations: (1) Plowing leaves one edge of the basin high and the other low, (2) discing works the soil outward and thus builds up the elevation of the ground surface at the edges of the basins, (3) any machine such as a harrow which is allowed to crowd the ridge pulls soil down upon the edge of the basin, (4) traffic or tillage operations on the ridge usually cause some soil to roll down on the edge of the basin. Harvesting of the outer row of row crops such as corn, beets, and beans has been difficult.

Maintenance of the ridges has also presented a definite problem. Grass has been difficult to establish and ridges soon became heavily infested with weeds. Alternately mowing and burning the weeds provided a good control, but these operations were time consuming and costly.

A major advantage of bench leveling was associated with high water use efficiencies. Under proper management, irrigation application efficiencies as high as 90 percent were measured. The benches also caught and held the scant rainfall within the crop area. The average rainfall is 13.69 inches of which 11.13 inches falls during the growing season, April through September.

The relatively narrow benches which cause some inconvenience in farming operations are a major reason why the farmers are somewhat reluctant to accept this type of farming. However, each year several farms are being bench leveled, and the system is gradually expanding. That the Government pays $65 per acre for bench leveling is an added incentive. Fifty-foot benches are now being built for $90-100. Recently constructed benches 200 feet wide cost $143 per acre. Usually the irrigation system needs altering and this increases the cost. Concrete pipe is the usual irrigation installation, and the Government again helps with an incentive payment of 9 cents per diameter inch per foot of pipe.

A recent wind storm in the Scotts Bluff area also sold several farmers on bench leveling. Winds up to 100 miles per hour completely destroyed young beet plants over much of the area and replanting was necessary. However, it was quite noticeable that no or little damage occurred to the plants on bench-leveled lands. This might be an item for study in our wind-erosion studies.

The ARS has just completed a rather extensive bench leveling program at the Newell, South Dakota, Station. Here benches have been graded to .25' per 100', .2' per 100', .1' per 100' and "dead level". An irrigation distribution system has been designed and is now out for bids. The distribution system has been designed so that up to 5 cfs. can be delivered to any bench which will provide a means of varying the Q values

during anticipated irrigation efficiency studies. The Newell area has always been confronted with a water shortage and the most efficient use of water is highly desirable. Last year the water supply for the Station allotment was 8 inches for the season. This year 3 inches is forecast. Precipitation averages 15.43 inches with 11.91 inches occurring from April to September. The Station has a clay soil which cracks upon drying and is extremely difficult to irrigate. The experiments here are the first with bench leveling on this type of soil.

In the Phoenix, Arizona, area bench leveling is quite common. The natural topography permits a different type of benching, however. Square benches consisting of 10 acres are formed as one unit (660' x 660") with a total drop of 1 ½ inches or 2 inches over the length of the run. The benches are level across the slope. Breaks in grade occur at the edge of each bench where service roadways are provided. Head ditches run between the benches, and drains are provided for each bench which collect the excess water and feed it into the next lower supply ditch. Experiments have shown that dead level benches on soils of low intake rate could be irrigated more efficiently and with less labor than those with the slight slope. However, the cost of working out the slope is usually not worth the effort or the difference in water saving. The natural slope of land is from 1 to 2 percent.

The ARS is trying to work out a procedure for evaluating the irrigation efficiency of level benches. The ordinary term "efficiency of irrigation" means the amount of water accounted for in the root zone divided by the amount of water applied. This is not entirely adequate. For an evaluation of level benches we are toying with the idea of a "distribution coefficient" as used in sprinkler irrigation. We are not yet prepared to propose a method of determining a "distribution coefficient", but the need is apparent.

Retardance of water flow by different crops is a factor effecting good irrigation on level benches. Sugar beets and beans have a high retardance near the end of the irrigation season. Tests indicate that water should be applied at about twice the rate at the end of the season as at the beginning. Alfalfa and corn require no change in the application rate during the season. For some unknown reason potatoes do not yield as well on level benches as under other methods of irrigation.

In summary it can be said that the trend in land leveling for irrigated areas is toward reduction in slope and that bench leveling with zero or very little slope is becoming more and more widespread throughout the West. The advantages are many but a few "bugs" are still to be worked out.

EQUIPMENT FOR LAND FORMING

by

Irwin L. Saveson[1/]

I won't spend very much time on this phase of land forming since most of you have had some experience in this field. Instead, I have asked Mr. Duke Faulkner of the Louisiana Agricultural Extension Service to discuss water leveling of rice land which involves a different use of land forming equipment. The machine work of land forming can be divided into three phases:

1. Rough grading, which comprises the major earth moving operation.

Originally this work was done principally with pan type scrapers and crawler tractors. In the past few years the self-loading scraper has made its appearance in the humid section and a number of them are now in use. They are pulled by wheel type tractors. From all indications, they have proven very successful and manufacturers are now building bigger machines to use on other earth moving work. Some of them are now being offered in 20-yard capacity. The advantages of them are their mobility and speed of operation. Their disadvantage is that they are harder to use in making light cuts to precision grade.

2. Finish grading, which comprises the smoothing and bringing the field to grade.

This operation is generally done with land levelers and there are a number of different sizes offered, the power requirement varying with the size of the machine. Two types of land levelers are offered on the market--the floating type and the rigid type.

The floating type has certain advantages in that it will plane to a closer grade where humps are in the field, whereas the rigid type will ride over them. The floating type requires minute adjustment as to spring tensions and drawbar height and the depth of operation is controlled from the seat, generally by hydraulic controls. This is an enticement for the operator to manually operate the machine rather than have it work automatically, thus interfering with obtaining a good grade.

The rigid type is practically foolproof, inasmuch as the depth of operation is set and the operator does not have a chance to change it while operating.

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3. Deep tillage, to remove the compaction induced by the earth moving machinery.

From our experience, a heavy field cultivator is a very adept tool for removing the field compaction caused by the earth moving operation. This is a tillage tool, not a subsoiling tool. When used as a subsoiling tool, it defeats the purpose of subsoiling by pulverizing the soil too fine, reducing the infiltration. In subsoiling, the purpose is to increase the water intake of soils, especially during the winter months, to obtain a deep soil moisture recharge.

The field cultivator not only breaks up the surface compacted layer, but blends the soil. This is especially true in fill areas. The curved teeth bring some of the soil at the lower depths to the surface and the surface fines sift into the voids left by the teeth. We will see this machine in operation on our field trip. Several different makes are found on the market. The one primarily used in the Delta is the Graham Hoeme, which takes considerable power. With wheel tractors several passes have to be made, increasing the depth after each pass until an adequate blending of the soil is obtained.

Without any further comments, I would like to introduce Mr. Duke Faulkner, who recently joined the LSU Agricultural Extension Service. Prior to this assignment he was with the Louisiana Agricultural Experiment Station at Crowley, Louisiana and had done considerable work in water leveling of rice land.

LEVELING RICE LAND IN WATER

by

Macon D. Faulkner[1/] and Roy J. Miears[2/]

INTRODUCTION:

Many factors have a direct influence on the yield of rice produced on any given field or farm. It has been recognized for many years that rice field weed control is often dependent upon the proper depth of flood water. Also, it is recognized that deep flooding can cause some damage to the rice plant. Therefore, the uniformity of flood water on rice is very important. In southwest Louisiana most of the rice field levees are spaced at 0.2' vertical intervals. This results in a normal flood range of 4.0 to 6.4 inches in depth. Not only is there a possibility that damage to rice will result from greater depth of water, but if greater volumes of water are required, then pumping cost will increase. On improperly leveled fields, a greater number of levees are required to obtain proper flooding conditions. Since the yields of rice are greatly reduced on levees, this will result in an overall field yield reduction. Levees are also a source of grass seed infestation for the rest of the field. A greater number of levees will require more labor for flushing and for flooding operations. Since the crossing of levees is damaging to farm equipment, maintenance expenses will be greater.

Dry land leveling has been a farm practice for many years. Regardless of the type of farm leveling machinery normally used, this does not change the general topography of the soil, but corrects comparatively small local depressions and hills. It is extremely difficult to move large amounts of soil by this method. However, this practice is responsible for increased rice yields because it aids in improved flooding conditions.

Because of the artificial hard plow sole pan and the true hard pan found in most rice soils, it is possible to operate equipment in flooded fields with ease. It was felt that a more complete and faster leveling of the soil could be accomplished in the water than on dry soil. By utilizing the water as a moving agent, greater amounts of soil can be moved and at faster rates than under dry conditions. By this method, the number of levees can be greatly reduced or on small fields completely eliminated.

The authors of this paper are reporting on leveling in water of rice soils at the L.S.U. Rice Experiment Station, Crowley, Louisiana. This method of soil leveling has created interest among rice farmers of the area.

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PROCEDURE AND EQUIPMENT

The field selected for this experiment was located at the Rice Experiment Station at Crowley, and contained approximately eleven acres in area. The field was considered to be representative of rice land in the South Louisiana area.

The field was surveyed by use of a farm level with elevation determinations being made at 50' x 50' intervals. Since stakes would be washed away during the operation in the water, stakes were placed at 50' intervals on the outside of the north and south levees for determining the East to West spacings and a line with tags at 50' intervals was used to determine the north to south intervals. All the stakes remained in place throughout the entire leveling operation.

A base map was drawn after the initial survey, showing contours on 0.2' vertical interval, this was accomplished by connecting points of equal elevation on the map by a line.

Random soil samples were taken from each quadrant of the field to a depth of from 4 to 6 inches, the depth was determined by the depth of the plow sole pan. These samples were used to determine nutritive elements as well as soil texture before the leveling operation.

The soil was then worked into a loose seed bed, by using a moldboard plow and disc harrow. The field was then flooded so as to completely wet the entire field. This water level was maintained throughout the water working operation.

The leveling operation was conducted by use of two tractors pulling a model 329 Eversman land leveler with the smoothing attachment removed, and a model 9PL Eversman land leveler which had had the frame length reduced and the adjusting mechanism removed. The tractors and levelers began moving soil from the high points of the field to the low generally in a circular pattern, raising the blades of the levelers at the edge of the lower portions of the field where a fill was desired, and allowing the soil to move away from the machine in a direction normal to the turning radius.

During the leveling operation in the water, measurements of water depth was taken by use of a ruler with a base pad attached so as not to extend into the mud. These measurements were taken by stepping off approximately 80' on line between the north and south line of stakes mentioned previously. This measurement was subtracted from 10" so as to make the land elevation consistant with the higher figures obtained. This measurement gave a good indication of how much soil was being moved as well as where the machinery operators should continue their work.

After work had progressed to a point where it was felt that all the soil had been moved, in water, that would be practical, the machinery was removed from the field. The water was contained in the field until such time as all silt had deposited from the water, so as not to lose top soil in draining.

After draining the field was allowed to completely dry then was worked into a good seedbed with a mold board plow and disc harrow. The field was then resurveyed as in the initial survey, to determine which areas that would vary more than 0.2' in extreme elevations. The areas that were found to have elevation differences of over 0.2' were either cut or filled using a model 329 Eversman land leveler and tractor.

Soil samples were then taken to determine the change in nutritive elements, textural class, and also what variation in depth of plow sole pan had accured.

The field was then surveyed again for calculation of the amount of soil moved for correlation of time per unit of soil moved.

RESULTS AND DISCUSSION:

From the preliminary or initial survey of the field, the extreme in elevation is from 97.75' to 96.94' or a difference of 0.81'. This is probably as much difference in elevation that could be changed by land leveling in water. This difference in elevation would mean that 0.81' or 9.71" of water would be necessary in the low portions of the field to barely cover the high portion of the field. Difficulty in machine operation is experienced in deeper water, as well as difficulty in determining where to work in regard to the low portions of the field.

The preliminary survey also shows over 4000 feet of levees existed before leveling began. Since normally levees are 10' in width this would mean that approximately one acre or over 9% of the field was devoted to levees. In eliminating the levees, not only can an increase in yields be expected but a much easier and economical farming operation can be enjoyed. The removal of levees will create the following benefits in rice farming.

1. Less levee making
2. Less levee maintenance
3. Easier flooding and draining
4. Easier cultivation
5. Less chance of levee washing
6. Higher yields
7. Easier combining of the rice
8. Facilitate irrigation of crops grown on the land other than rice
9. Less grass infestation from levees

From the measurement of water depth during the leveling operation in the water, it was noted that a difference of 0.4' in elevation still existed. On the basis of this observation work was continued in the water as long as the soil would move freely. One very important part of this type of land leveling is to be able to do all the necessary work in water in one day, if possible. After remaining under water over night and not having been worked the soil becomes compacted and very difficult to move.

After draining the water from the field, a difference of 0.4' in elevation still existed but on a very localized basis. All variations in elevation were changed to within 0.2' by using the model 329 Eversman land leveler and tractor.

The final relative elevations existing in the field after all leveling had been completed are within 0.2' which is considered accurate enough for rice irrigation.

Although the general slope of the field is toward the south after all leveling is complete, a true grade line need not be followed for successful rice irrigation. As noted previously the allowable variation in elevation is 0.2' for rice irrigation. This small difference in elevation will normally cause no trouble in draining, since drains are plowed in the fields after planting and prior to irrigating. These drains will usually carry all rain water before the first irrigation and drain the field when the irrigation water is removed.

Results of the chemical analysis of the soil are shown in Table 1. There was greater differences between samples than between times of sampling. Therefore the soil leveling operation apparently had no effect on the availability of plant nutrients as measured by the analysis.

The sample taken prior to the land leveling in Quadrant III showed high available phosphorus. This area had high phosphorus applications on clover two years prior to this operation. In the land leveling operation, this soil was spread to other parts of the area.

As shown in Table 2, only a very slight change in the texture of the soil occurs during the leveling operation. A slight decrease in clay content occurs and an increase in silt. Some change in sand content is noted, but is not significant to make any definite trend.

No great change can be noted in the plow sole pan as far as depth is concerned. However, in the portions of the field that were highest or lowest, increases were noted, in that the places that were originally low the plow sole pan was as deep as 12" while on the original highs the plow sole pan was as shallow as 4". These differences in plow sole depth were only in small areas, and are felt to be of no great importance in regard to the overall characteristics of the field. The slight change in plow sole pan depth is due partially to the state of the top soil during leveling operation. During the work in the water the top soil is in an almost fluid state and moves away from the leveler blade, while the plow soil pan is fairly compact and can be moved while under water.

Normally great accuracy is not as necessary as indicated by this experiment in surveying the land. Even though levees are usually located at 0.2' vertical intervals, there will almost always exist between any two levees a variation greater than 0.2'. Therefore, from a standpoint of time requirements for this experiment, only the actual leveling and land preparation prior to leveling is considered. The total time required to work in the water was 18 hours and 20 minutes, 15 hours and 30 minutes after drying, and 14 hours to prepare the land.

This was a total time of 47 hours and 50 minutes or 4 hours and 20 minutes per acre. The time is based on use of tractor and one man.

Using average cuts and fills at the four corners of the 50' x 50' grids to calculate earth moved, a total of 768 cubic yards of earth was moved, or 69.8 cubic yards per acre.

From experience, at the Rice Station, machinery can be expected to depreciate faster in water than on dry land operations. The most trouble developed in wheel bearings, tractor rear axel bearings, and transmission. Mud and water began to enter the transmission housing through the axel housing as the axel bearings began to go bad. No comparative analysis has been made as far as depreciation between dry leveling and leveling in water.

To assure the most efficient operation of equipment, the operators should be made completely familiar with the land to be leveled in water. This may be accomplished by a survey or through experience the operator may have gained from irrigating the land.

One very attractive aspect of this type of land leveling, as far as rice farmers are concerned, is that they will either own or have access to the necessary equipment to successfully complete the operation. Normally the only equipment necessary is a tractor leveler and equipment to prepare a seedbed.

The tractor to be used in the water should be a 50 H.P. tractor or greater since fast movement is necessary for good wave action and consequent smoothing of the soil. The movement of soil is dependent on wave action to a large extent both for moving the soil and spreading, since a wave will tend to carry soil until it reaches a low point or an area with increased cross section, as far as water depth. When the water and soil reach this increased cross sectional area, a reduction in velocity occurs and the soil will deposit from the water.

In fields too large or with an elevation differential too great to level, to completely eliminate all levees, the practice of land leveling in water can be used to eliminate every second levee and to straighten the remaining levees. This practice is accomplished by making levees on 0.4' contours and leveling in water between these levees. Since the desired elevation differences is 0.2', only 0.1' of soil has to be moved from the high portion to the low portion of the area inclosed by the levees run

on 0.4' vertical intervals. This practice creates the problem of having a 0.2' elevation differential across levees, which will increase the possibility of washing the levee and consequent crop damage due to rains and deep irrigation water.

The possibility of levee washing can be partially eliminated by using permanent levees, built higher than necessary for natural 0.2' levees.

Table 1. The chemical analysis of rice soil prior to and following leveling in water.

Available Element	Prior to leveling: Quad. I	Quad. II	Quad. III	Quad. IV	Avg.	Following leveling: Quad. I	Quad. II	Quad. III	Quad. IV	Avg.
P, p.p.m.	17	21	63*	14	17	19	21	19	20	20
K, p.p.m.	26	48	48	26	37	35	35	35	26	33
Ca, p.p.m.	1123	950	778	994	961	1080	950	907	907	961
Mg, p.p.m.	231	277	203	221	233	251	263	251	238	251
Ph	5.7	5.4	5.1	5.6	5.5	5.8	5.9	5.9	5.9	5.9

* This quadrant had high applications of phosphorus applied to clover in previous years. Not included in average.

Table 2. Mechanical soil analysis before and after leveling.

Sample	Before leveling: % Sand	% Clay	% Silt	Textural Class	After leveling: %Sand	% Clay	% Silt	Textural Class
Quad. I	7.6	27.1	65.3	Silt loam	7.6	21.4	71.0	Silty clay loam
Quad. II	6.8	24.7	68.5	Silt loam	7.6	19.4	73.0	Silt loam
Quad. III	8.9	21.6	69.5	Silt loam	7.6	19.4	73.0	Silt loam
Quad. IV	7.2	27.8	65.0	Silt loam	7.6	19.8	72.6	Silt loam

LAND LEVELING REQUIREMENTS FOR IRRIGATION
(AND HOW THEY DIFFER FROM LAND GRADING FOR DRAINAGE)

by

Lester F. Lawhon[1/]

Land leveling for irrigation is for the purpose of facilitating uniform soil moisture distribution within the range most advantageous for crop production. From the purely scientific point of view this can best be accomplished with an eyedropper - eliminating physical, economical, sociological and other practical aspects of the problem. It is not my intent to present an argument as to the easiest, least costly, or most commonly accepted methods of changing land surfaces.

I hope to present to you the land leveling requirements for irrigation and let you decide how they differ from land grading for drainage. The only thing I know about drainage is that it is necessary to dispose of excesses and waste products - I hope it will take care of both my necessities and my mistakes.

There are certain hydraulic principles which must be adhered to in the design, construction and operation of an irrigation system. These represent physical phenomena with which we must cope. Newton's and Darcy's laws and Bernoulli's theorem are outstanding examples or expressions of these physical phenomena. In addition to these scientific phenomena there are the practical aspects represented by the design of farm machinery, the physical aspects represented by uniformity or repetition of operations, and the economic aspects related to automation. All of these latter are interrelated.

I will attempt to give examples of variations in topography and explain how they affect both the distribution of irrigation water and farm operations. From these examples I hope you will be able to draw your own conclusions.

There are three basic methods of surface irrigation - (1) the basin or impounding method, (2) the balanced advance-recession method, and (3) the controlled flow method. In the first method water must be rapidly applied to an area and held in place until absorbed into the soil. The second method balances rate of application, rate of flow over the land surface and rate of recession with rate of intake into the soil. The third method relies upon quick coverage of an area and then adjustment of the rate of application to equal the rate of intake.

Slopes in direction of irrigation present problems in continuity and uniformity of flow. Either irrigation or drainage can be blocked by a reversal of slope.

This problem can be alleviated by a minimum of earth moving to form an increasing but continuous grade.

1/ Irrigation Engineer, SCS, E & WP, Ft. Worth, Texas

This may be all that is needed for surface drainage but is not conducive to uniformity of irrigation water distribution. A uniform or slightly decreasing grade is much better adapted to irrigation.

On the other hand land surfaces which are perfectly level are the simplest for irrigation but it may be difficult to obtain adequate surface drainage under these conditions.

The land slopes normal to the direction of irrigation also present problems. Undulating cross-slopes may actually be conducive to more rapid surface drainage, but level or slight uniform grades are much easier on which to handle irrigation water.

Another major difference in irrigation and drainage requirements is in slope lengths in direction of water flow. This difference is related to soil permeability or internal drainage. Generally speaking the irrigation system length of run is inversely proportional to soil permeability whereas the drainage length of slope is directly proportional to soil permeability.

From the standpoint of irrigation and drainage and farm operation the leveling design which permits the efficient operation of all three is most desirable. Experience indicates that leveling into planes which are uniform in length, width and slopes can be most compatible to all three needs.

LIMITATIONS OF LAND FORMING (SOILS)

by

D. L. Fontenot[1/]

Data can be produced to show almost any results desired relative to certain crop yields before and after land forming. Perhaps the most controversial of such data is yields on deep cut and fill areas the first year or so after the practice is installed. Our observations are just as variable as that contained in the literature. I would like to spend the next few minutes discussing some of the reasons why benefits or depressions as measured by crop yields should and will exhibit such trends.

Let's list some of the factors or conditions known to influence crop response after land forming, or more specifically, land leveling or land grading.

1. Depth of cuts and fills.

2. Physical and chemical nature of the soil being disturbed.

3. Soil moisture conditions during the earth moving operations.

    a. Excess moisture
    b. Unusually dry conditions

4. Rainfall patterns and amounts during the growing season following leveling.

5. Prior physical condition of the soil on areas being filled, with this question asked:

    a. Was this properly broken, or was fill material placed on old surface without breaking?

6. Differential settling of fill areas.

7. Degree of artificial drainage provided after leveling or grading.

8. Prior conditioning of the disturbed areas with soil improving crops prior to planting cash or test crop.

9. Amount and kind of fertilization following disturbance.

10. How many years the yield tests were conducted, and what kind of maintenance was provided?

1/ State Soil Scientist, SCS, Alexandria, Louisiana

There is no doubt, in my opinion, that many of these factors are interrelated. Also, any conclusions drawn too soon and without thorough evaluation of potential factors involved are very likely to be misleading.

Perhaps we would get the most from this discussion if we concentrated on the closely related items: (1) depth of cuts and fills, and (2) physical and chemical nature of the soil being disturbed. My comments are specific for Louisiana conditions, but are applicable for most major river bottomlands and low terraces, and loessial soils in this rainfall belt.

Probably less than five percent of the above soil areas now considered practical to land level, or land grade, are ideal from a soil profile or soil layers standpoint. Ideal soils would be unstratified phases of such series as Yahola, Commerce, and Gallion, having two or more feet of medium textured surface.

In addition to the above, slightly sloping, undulating areas having sandy ridges and fine textured depressions, could be considered ideal sites for land forming. This is in part because of the value and benefits resulting from altering both topography and soil.

Unfortunately, most of the soils having topographic tolerances for land forming have one of five, or sometimes two of the following undesirable profile characteristics.

1. Medium textured shallow surfaces with fine textured (clayey) subsoils.

2. Medium textured surface soils with coarse textured subsoils. These almost always require deep cuts and fills because of topography.

3. Soil with fragipans so common in loessial areas.

4. Soil pattern comprises combinations of the above, including well and poorly drained soils in the same field.

5. Clayey surfaces with shallow coarse textured subsoils.

Each of the above conditions present different problems to the engineer and agronomist. It is safe to say they are a problem to the soil scientist although these conditions are usually reflected in the soil series, type, or phase.

Any accrued gains in crop yields following land leveling or land grading should be evaluated with several items being considered. The majority of land grading is done for two purposes: (a) to improve surface drainage, and (b) to facilitate irrigation. Very often the purpose is a dual one with benefits resulting from both. In some cases, soil conditions are so severely

altered that sustained increases in crop yields may not result specifically from improvement in drainage or irrigation efficiency. For example, the exposure of significant areas of clay or very sandy material by leveling a medium textured, clay subsoil, or coarse textured subsoil, may create several problems the practice was designed to accomplish or improve. Being specific, let's use Miller, Sharkey, Iberia, and Baldwin silt loams having a surface 6 inches to clay or silty clay. Land leveling or grading undoubtedly will expose clay in part of the field, or at least reduce the silt surface by several inches. Also, parts of the field will have a deeper silt covering. These two soil textures represent extremes in the moisture characteristics and properties of soil material. These in turn influence both surface and internal drainage as well as factors in irrigation design and efficiency.

Crop yield data gathered over many years and for many "so-called" wet and dry years by soil series, type, and phase clearly indicate the following:

Under the same management, yields of cotton, sugarcane, and some other crops are on the average 25 percent to 30 percent less on the same soil series of the clay or silty clay type, than on the medium textured type, even if only six inches or so to clay. Very similar reductions in yields have been noted between the same crops grown on coarse or very sandy textured surface soil types, as compared to medium textured surface soils for comparable soil series. Examples of soil series with phases usually requiring deep cuts that may have very sandy or coarse textured lower subsoils are: Gallion, Hebert, and Pulaski.

In the two extreme but extensive examples just presented, part of a field leveled in a manner that would expose these less desirable soil textures can expect to be permanently less productive. With this man-induced handicap, the practice has little potential of becoming an economic success. It is true that coarse textured surfaces can sometimes be practically altered by deep plowing to improve surface texture. Unfortunately, altering exposed clay surfaces of soils like Miller, Sharkey, Roebuck, Portland, Iberia, and Baldwin, is not practical because the clay extends down for several feet.

Most of the soil series derived from loess have fragipans. These horizons, although usually silt loams, have undesirable structure which seriously restrict the movement of water and air through the soil profile. The nearer to the surface the fragipans occur, the shallower the effective root zone for most crops. Removal of surface soil either by erosion, leveling, or grading reduces the potential to produce annual crops for such soil series as Richland, Oliver, Calloway, Grenada. Another influencing factor is that the B horizon of these soils are often heavy silty clay loams as compared to the more desirable silt loam surface. It is not uncommon to find two or three loessial soil series in a field of less than twenty acres. This alone presents problems in design and construction.

In the coast prairie and to some extent in a few parts of the loessial terraces, most soil areas have claypans over medium textured surfaces. Again removal of surface soil by erosion, leveling, or grading make the soil less deep for plants. Experience in removal of pimple mounds in the rice area of Louisiana clearly demonstrates the need to excavate below normal ground depth in destroying the mound. This allows a few inches of silty material to be spread over the clay exposed under the mound. Where this is not done yields of rice are reduced under the original moundy areas. Reduction in crop yields would be more serious for non-irrigated crops.

Some of the soil series in this association are Crowley, Midland, Acadia, and Carroll silt loams.

Up to this point most of you probably feel I am biased against land leveling and land grading. Actually I feel these practices can be very beneficial when properly designed with consideration given to the finished surface soil as a media for plant growth. We need to fully evaluate the topography and the soil characteristics and properties of the original soil material and soil profiles to be disturbed or exposed. Modificatinns can and should be made in design and construction in order to achieve the maximum benefits to future crops.

The engineer can use assistance from soil scientists and agronomists. The usual soil survey is normally not of sufficient detail to provide the needed soil information for land forming where deep cuts and fills are required. By the same reasoning, soil conservationists and agronomists cannot usually recommend the same kind and degree of management for such treated areas.

It is a challenge and a necessity that the design and construction engineer request and get all the available soil and crop data needed to insure the maximum effectiveness of any kind of land forming requiring major alterations on most of our soils. As is usually the case, sustained benefits to safe and economical crop production will decide the success or failure of such practices in the final analysis. The limitations of land forming are greatly reduced when all the facts are considered, evaluated, and applied.

PROBLEMS RELATED TO DETERMINATION OF RECOMMENDATIONS FOR LAND FORMING PRACTICES FOR SURFACE DRAINAGE

by

L. W. Herndon[1/]

A. What effect should land forming practices have on recommendations for drainage ditches?

   1. Is the rate of runoff changed to the extent that we should use different drainage curves for ditch design?

   2. The SCS has developed spacings of surface field ditches for certain soils under conditions of normal cultivation - no land forming. How do the different land forming practices affect the requirements for spacing?

   3. How do land forming practices affect the depth requirements of surface field ditches?

B. The matter of economics is important. We feel that a substantial per acre cost for land forming for improved drainage can be justified but supporting data are skimpy. We would like to have average costs of establishing the following practices on the principal soils needing drainage and the average annual monetary benefits for principal crops:

   1. Land grading for drainage.

   2. Land smoothing for irrigation and drainage.

   3. Land leveling for irrigation

   4. Surface field ditches - an evaluation of benefits to drainage where laterals and mains are provided but surface field ditches are provided on one job and omitted on another job which is identical except for elimination of the surface field ditches.

   5. Bedding (crowning).

C. What effects do climatic changes have on these surface drainage requirements?

   1. What changes in spacing and maximum length of surface field ditches should be made between an area with 60 inches annual rainfall and one with 40 inches?

   2. What effect does mean annual temperature have on draiange requirements? In other words for the same general soil characteristics, crop, and rainfall should there be any difference in surface drainage criteria between the Gulf Coast and Northern Arkansas?

1/ Drainage Engineer, SCS, E & WP, Ft. Worth, Texas

THE TRACTIVE FORCE METHOD AND ITS APPLICATION TO OPEN CHANNEL DESIGN

by

John M. Laflen[1/]

The tractive force method can be used in the design of open channels. When data become available, this method will present a more exact design of open channels than the limiting velocity method. It will provide a method of design which will not require the assumption of uniform flow which all empirical velocity equations use. Uniform flow rarely occurs, and the assumption of uniform flow may, in certain instances, lead to appreciable errors in design. The limitations of the tractive force method at the present time include the lack of applicable data and the complexity of the necessary computations. Research must provide charts and tables developed with the aid of an electronic computer before the method can be used extensively.

The tractive force method presents a means of evaluating the shear at the interface between the flowing water and the channel bed material. This shear is the force which causes erosion of the channel bed material, and is called the tractive force. The tractive force which a channel bed can withstand has been called the "critical tractive force", the "maximum allowable tractive force", and the "limiting tractive force". In this paper these terms are synonymous.

In 1786, du Buat[2/] was the first to express friction between running water and a river bed as the product of the slope of the channel and weight of the water overlying the bed.

Du Boys[3/] later expanded this into a general theory. Since that time, tractive force has gradually developed. While it has been used rarely in the United States, it has been used frequently in Europe. Extensive research involving tractive force has been carried on in Europe, primarily in laboratory studies with non-cohesive soils.

Theoretical Analysis

Consider an open channel of infinite width as shown in Figure 1. By the principal of conservation of energy, the total energy at one section of the channel is equal to the total energy at a section downstream plus

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1/ Agricultural Engineer, ARS-SWC, Baton Rouge, La.

2/ Par E. du Buat, "Principles d'Hydraulique," Paris, 1786, cited by Hans Kramer, "Sand Mixtures and Sand Movement in Fluvial Models," Transactions of the American Society of Civil Engineers, 100:799, 1935.

3/ Par P. du Boys, "Le Rhone et les Rivieres a Lit Affouillable," Annales des Ponts et Chaussees, 1879, II, Ibid.

the work required to overcome the boundary shear of the fluid in moving the distance between sections. Then the energy relationship which exists between two sections is

$$\frac{V^2}{2g} + D + dh = \frac{(V + dV)^2}{2g} + D + dD + \frac{T}{WD} dx \qquad (1)$$

where V is the mean velocity, D is the depth of flow, dh the height of the bottom above a horizontal plane, dV the change in velocity between the sections, dD the change in depth between the sections, T the tractive force exerted on the channel by the flowing water, W the specific weight of the fluid in the channel, dx the distance between the sections, and g the acceleration of gravity. Solving for T, equation (1) becomes

$$T = WD \left(\frac{-2VdV - dV^2}{2g\ dx} - \frac{dD}{dx} + \frac{dh}{dx} \right) \qquad (2)$$

However, dV would ordinarily be quite small, and dV^2 could safely be neglected, and equation (2) becomes

$$T = WD \left(- \frac{V\ dV}{g\ dx} - \frac{dD}{dx} + \frac{dh}{dx} \right) \qquad (3)$$

dh/dx is the slope of the channel and can be replaced by S. From the equation of continuity, V = q/D, and $\frac{dV}{dx} = - \frac{q}{D^2} \frac{dD}{dx}$, where q is the flow per unit width in the channel..
Then equation (3) can be written as

$$T = WD \left(\frac{q^2}{gD^3} \frac{dD}{dx} - \frac{dD}{dx} + S \right) \qquad (4)$$

Equation (4) is valid for laminar, turbulent, streaming, and shooting flows. In uniform flow, the term dD/dx is zero, and equation (4) reduces to the du Boys' tractive force equation

$$T = W\ D\ S \qquad (5)$$

In using equation (4), S is negative when the channel slopes in the direction of flow, and T will be a negative number. This is of no consequence, since we are interested only in the numerical value.

Correlation of Critical Tractive Force to Physical Properties of the Soil

Various investigators have worked on the problem of correlating critical tractive force to various properties of the soil in both cohesive and noncohesive soils. The results of their studies, while promising, indicate that a great deal of research is still necessary.

E. W. Lane[4] of the Bureau of Reclamation has developed a design procedure for canals in non-cohesive materials. The results of his preliminary

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4/ E. W. Lane, "Design of Stable Channels," Transactions of the American Society of Civil Engineers 120:1955.

studies indicate that for coarse non-cohesive materials, the limiting tractive force in pounds per square foot equals one-half the diameter in inches of a particle such that 25% of the material in which the canal is constructed is coarser. For design purposes, he suggests that the value of .4 be substituted for .5 in order to allow for a small factor of safety. Mr. Lane also includes a figure showing the maximum tractive forces on the bottom and sides of channels of different shapes and sizes. Also included in the report are values of limiting tractive force obtained by converting limiting velocity data as given by Etcheverry, Fortie and Scobey, and the U.S.S.R. Several assumptions were necessary to convert the limiting velocity data to values of limiting tractive force.

Smerdon[5/] conducted a study on 11 Missouri soils exhibiting varying cohesive properties in 1959. He related critical tractive force to various cohesive properties of the soils tested. His results indicated that the critical tractive force for cohesive soils was best correlated with the plasticity index and the dispersion ratio, although excellent correlation also exists between mean particle size and the percent clay. His results are shown in Table 1.

Table 1. Smerdon's Correlations Between Critical Tractive Force and Physical Properties of the Soil

Variables (T_c and)	Correlation Coefficient, r	Regression Equation
Plasticity Index (I_w)	0.896	$T_c = 0.0034(I_w)^{0.84}$
Dispersion Ratio (D_r)	- 0.892	$T_c = 0.213(D_r)^{-0.63}$
Mean Particle Size (M)	- 0.860	$T_c = 0.074 \times 10^{-28.1M}$
Percent Clay (P_c)	0.980	$T_c = 0.0103 \times 10^{0.0183\ P_c}$

Dunn[6/] also conducted a study in 1959 concerning the possibility of estimating the tractive resistance of cohesive channel beds based on information obtained from soil tests, namely the Atterberg Limits, particle size analysis, and vane borer tests. His results indicated that the critical tractive force for cohesive soils could be calculated by using the equation

$$T_c = .02 + \frac{(Sv + 180)}{1000} \tan (30 + 1.73\ P.I.) \qquad (6)$$

where S_v is unit shear strength as found by a vane borer test and P.I. is the plasticity index.

5/ E. T. Smerdon and R. P. Beasley, The Tractive Force Theory Applied to Stability of Open Channels in Cohesive Soils, Agricultural Experiment Sta., Research Bul. 715, University of Missouri., Columbia, Mo.: October 1959.

6/ Irving S. Dunn, "Tractive Resistance of Cohesive Channels," American Society of Civil Engineers, Soil Mechanics and Foundations Divisions, 85:14, June 1959.

This writer[7] conducted a study on five of the soils which Smerdon tested in an attempt to determine the effect of compaction on critical tractive force. The results of the study indicated that as the bulk density of the soil increased, critical tractive force also increased. However, the tests were performed in a hydraulic flume on disturbed soils, and the range of bulk densities were not those ordinarily encountered in the field. No correlation between critical tractive force and bulk density and any other physical property of the soil was found.

All of the laboratory studies up to this time have been on channels which have no vegetation. This factor alone limits the extent to which the accumulated data may be applied. For channels which do not have continuous flow, data from laboratory tests would not be applicable.

Application of the Tractive Force Method to Open Channel Design

The application of the tractive force method to the design of open channels is much more complex than application of the limiting velocity concept. When changes in grade of the channel or changes in the cross-sectional dimensions are encountered, the design problem becomes even more complex.

A typical procedure which might be followed is listed in the following order:

1. Estimation of required channel capacity.

2. Selection of the maximum allowable tractive force for the material of which the channel bed is comprised. This may require separating the channel into reaches having similar bed material or vegetation.

3. Selection of the desired channel shape.

4. Selection of a set of trial dimensions for the channel.

5. Calculation of the water surface profile for reaches of the channel using the appropriate back-water equations for each reach of the channel[8].

6. Calculation of tractive force using equation (4).

7. Comparison of calculated values of tractive force with the maximum allowable tractive force.

7/ J. M. Laflen and R. P. Beasley, Effects of Compaction on Critical Tractive Forces in Cohesive Soils, Agr. Expt. Sta., Res. Bul. 749, Univ. of Missouri, Columbia, Missouri: September 1960.

8/ Van Te Chow, Open-Channel Hydraulics, New York: McGraw-Hill Book Company, Inc., 1959, Part III.

8. Repetition of steps 4 through 7 until the calculated value of tractive force is nearly that of the maximum allowable tractive force. This is necessary in order to design the most economical cross section, as well as one which will not aggrade or degrade.

The most difficult and tedious part of the design problem would be the numerical computations of the water surface profile. The computations would have to be made using a computer and the data condensed into tables and charts before the tractive force method could be used in the design of all earth channels.

One application of the tractive force method to the design of open channels that I know of has been handled in a method similar to what I have listed. D. K. McCool of the University of Missouri will present a paper at the ASAE meeting in June at Ames, Iowa on the tractive force method. In McCool's study, he utilizes Smerdon's and Laflen's data and uses a computer to make the numerical computations in order to design parallel terraces. I believe that his data will be published in an experiment bulletin at the University of Missouri, and that it will recommend the' spacing, dimensions, maximum changes in slope, and maximum length of reaches of the terraces for certain land slopes on certain soils.

Conclusion

It is this writer's opinion that the tractive force method does offer a means of improving the design of open channels. However, data available at the present time is not of sufficient quantitiy or quality to use in designing open channels using the tractive force method. Also, the backwater equations used have some of the weaknesses inherent in the limiting velocity method of design, and cannot predict exactly the water surface profile for a reach of channel. When data becomes available, however, it should be possible to present the data in tables and graphs for the use of personnel in the field designing the channels.

HYDRAULIC CONSIDERATIONS OF CHANNEL FLOW

by

W. C. Little[1/]

The question of what flow conditions exist in open channels is of concern to the engineer. From the standpoint of the hydraulic engineer, one would determine the resistance forces due to viscosity and channel roughness first and then conclude what flow conditions exist. But this cannot always be done by the practicing conservation engineer. The conservation engineer depends primarily upon design criterion and data compiled by field trials. These data are generally compiled by the use of Manning's equation, which is:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

where V is the average velocity in feet per second, n is Manning's roughness coefficient, R is the hydraulic radius in feet, and S is the slope of the channel bed. Evidently, without some definite information on the value of Manning's "n" the equation is of no value to the design engineer. This had led to extensive studies to determine the value of "n" for the multitude of physical conditions existing in open channels. Also, there are many different types of open channels such as open ditches for surface water outlets, open ditches for sub-surface drainage, crop land terraces, diversion channels, meadow strips, vegetated waterways, and channels between crops for furrow irrigation. Some of these channels are primarily for erosion control and some specifically for drainange. For proper design of any of these channels, consideration of topography, types of vegetative cover (if any), hydrologic factors, and farm practices is required.

An extensive amount of literature exists regarding flow in open channels. Ramser (4) performed experiments to determine what "n" values should be applied for the design of drainage channels. Palmer (2) presented graphical solutions for flow characteristics. Palmer and Law (3) evaluated Manning's "n" for vegetated waterways and suggested a graphical method of channel design where "n" was plotted as a function of the product, velocity and hydraulic radius. He presented this graphical solution for many types of grasses and also many different channel cross sections. Ree (5) has presented graphical solutions for many types of grasses and channel cross sections also. Ree stated that the relationship of "n" to VR is characteristic of the vegetation and is influenced mainly by the length of the vegetation and partly by the density. However, this paper will attempt to show that this same general relationship exists for bare soils as well. Kruse (1) has shown that "n" is a function of the product, velocity and hydraulic radius for bare soils.

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Experimental Procedure

A V-type channel, 50 feet long, with 1:4 side slopes was installed on a mechanically tilted plot and underlaid with plastic film to prevent infiltration so that uniform flow could be obtained. The channel was shaped in Cecil clay with 1:4 side slopes. To obtain a channel cross-section similar to that encountered in the field, a flow rate of approximately 0.156 c.f.s. was applied and allowed to run for a period of two hours. Some erosion occurred as is shown in Figure 2. After this cross-section was reached, a thin coat of powdered cement was applied to insure a constant channel shape throughout the experiment. The flow into the channel was controlled by a valve, and the flow measured at the lower end of the channel by a 60° V-notched weir. A point gauge, mounted on rails parallel to the channel bottom, was used to measure the stream depth at intervals of five feet within the center 30 feet to eliminate any end effects. The flow rate was varied from .011 to .240 c.f.s. for slopes of 0.1 percent and 0.25 percent.

Results

Results of the experiment are presented in Table 1. Figure 1 shows the variation of Manning's "n" with the hydraulic radius. For very small flows (0.01 c.f.s.), "n" becomes relatively high and depends primarily upon the hydraulic radius. Above hydraulic radii of 0.090 "n" becomes constant and does not depend upon the flow characteristics. However, it is evident that "n" is also a function of slope for the ranges tested here. The range of flow rates used in these tests represent the flow rates encountered in furrow irrigation and drainage from furrows during intense storms.

Summary

When working with small rough channels, Manning's "n" is dependent upon the flow characteristics. This study is by no means conclusive of this fact, but indicates that boundary roughness has a considerable and variable effect on the properties of turbulent flow in small rough channels. This change in Manning's "n" with flow characteristics also indicates that relative roughness rather than absolute roughness should be considered for small flows. Experience and discretion should certainly be used in the application of Manning's equation to flow in small rough channels.

Table 1. Flow characteristics for channel

Stream Width Ft.	Stream Depth Ft.	Area Sq. Ft.	Hydraulic Radius Ft.	Discharge c.f.s. 0.1%	Discharge c.f.s. 0.25%	Velocity Ft./Sec. 0.1%	Manning's "n"* 0.1%	Manning's "n"* 0.25%
.91	.070	.0460	.0496	.011	.0195	.239	.0267	.0237
.98	.080	.0551	.0546	.016	.029	.290	.0234	.0204
1.06	.090	.0658	.0604	.024	.043	.365	.0199	.0176
1.12	.100	.0764	.0664	.032	.055	.420	.0185	.0170
1.18	.110	.0873	.0721	.040	.071	.458	.0178	.0158
1.24	.120	.100	.0787	.051	.087	.510	.0169	.0157
1.30	.130	.113	.0843	.062	.100	.550	.0165	.0162
1.33	.140	.127	.0920	.072	.110	.567	.0170	.0175
1.43	.150	.140	.0946	.092	.139	.657	.0149	.0156
1.50	.160	.155	.101	.106	.160	.685	.0150	.0157
1.57	.170	.170	.105	.120	.180	.706	.0149	.0156
1.63	.180	.187	.110	.133	.195	.711	.0152	.0164
1.72	.190	.203	.114	.148	.220	.730	.0152	.0161
1.80	.200	.220	.119	.162	.240	.736	.0155	.0165

* Calculated from $Q = \frac{1.49}{n} AR^{2/3} S^{1/2}$

RESEARCH PROGRESS IN LAND FORMING AND SURFACE DRAINAGE

by

Irwin L. Saveson[1]

In reviewing the progress of land forming research, we must realize that in a short period of time we have moved a very exacting, revolutionary agricultural practice from the arid section of the United States to the humid section, involving different climatic conditions, different farming conditions, different cropping conditions, and different soil conditions. Thus, many adjustments were necessary to fit land forming to the humid section. Human complexes, such as cost, removal of top soil, and apprehension of the magnitude and precision of the job, also complicated the situation.

The big demand for land forming work in the Lower Mississippi River Valley came in the early 1950's to facilitate irrigation of cotton and general crops during the drought years. Previous land forming work had been done for rice and sugar cane land, both specialized crops using specialized field arrangements. The research work started in Louisiana in 1956 had been confined primarily to sugar cane land. It was a modification of land forming, called turtle backing or cut crowning in the sugar cane area, and was done primarily to facilitate drainage. Shortly after the first land forming work was done in the cotton and general farming areas, the drainage benefits were soon recognized. Today the majority of land forming work is done to facilitate both drainage and irrigation in the alluvial area of the Lower Mississippi River Valley.

Dr. van Bavel of the Agricultural Research Service has studied the rainfall characteristics of the Lower Mississippi River Valley to determine the probability of drought and water surplus in its agricultural soils. By means of machine tabulations and computers he evaluated weather records for 25 years or more at 81 locations in this area to determine the daily soil-water balance.

This study reveals that annual rainfall is not distributed uniformly. It exceeds the crop water requirements by 15 to 25 inches in northern Arkansas and by more than 30 inches in Louisiana. Most of this excess occurs in the winter and spring months, December through May.

In five out of ten years there is an average monthly excess of 3.5 inches from December through February and 2.0 inches from March through May in the Lower Mississippi River Valley. June through August are moisture deficient months in five out of ten years, with an average monthly moisture deficiency of approximately 2.5 inches for June, July, and August, and 1.69 inches for September. Therefore, land forming has a dual function in the humid area by facilitating both drainage and irrigation.

1/ Project Administrator, ARS-SWC, Located at L.S.U., Baton Rouge, La. - a joint undertaking with the Louisiana Agricultural Experiment Station.

Coming back to the progress of the research work, due to the nature of the work the majority of it has been applied research. Both ARS research and SCS operations have made substantial contributions by developing techniques for doing the engineering and earth-moving operations, with both agencies working hand in hand. Since it is applied research, many of the conclusions are based on field observations and surveys.

The progress of research will be discussed on the basis of three types of major crop land: sugar cane, pasture, and general crop land (principally cotton).

Sugar Cane Land

For those of you who are not acquainted with the sugar cane field layout, the fields are divided into cuts from 150 to 250 feet wide and approximately 1000 feet long, bounded by a drainage ditch on each side and a headland across each end. The ditches and crop run parallel to the main slope of the land. Since the crop rows are 14 to 18 inches high · 6 feet apart and parallel to the lateral ditches, cross drains or ditches cutting across the rows are necessary to carry the water to the lateral ditches. There are generally four of these ditches (known as quarter drains) to the cut. In forming sugar cane land the cut is formed with the crown similar to a highway. Where there is ample sidefall to the field the cuts are formed in a plane sloping from ditch to ditch. Since the sugar cane cut is narrow and the earth-moving distance is short, an experienced operator can generally grade them by eye with a few indicator points. Only a few differential levels are required to establish these points.

Bulldozers are the most efficient equipment for forming sugar cane land since the earth-moving distance is short. After forming with the bulldozer the land is smoothed by a land leveler or a motor grader. Motor graders often are used for the complete job but are much slower.

On approximately 500 acres under test, an increase of 5.81 standard tons of cane was obtained on the formed land over the land which was not formed. Cost of the work was approximately $45 per acre. In most instances the cost was liquidated the first year. There is a relationship between the waterponding pockets and yields. The smoothed fields having no pockets produced 4.59 more tons of sugar cane per acre than the land having surface ponding of 2 inches or more on 53% of the land. This indicates the need for precision work in land forming because sugar cane is grown on beds or rows 14 to 18 inches high 6 feet apart.

In 1957 ARS and SCS initiated a different type of drainage system on sugar cane land similar to that used in the cotton section of Louisiana. This test area is on the Margaret Plantation, Port Allen, Louisiana, which we will visit on our Thursday field trip. It comprises approximately 29 acres formed and smoothed to a definite plane of .8 ft. fall per 100 ft. Each row leads to a flat sloped ditch, which is crossed by the farm implements. This system has reduced the amount of land in ditches by 4.5% and will cost from $60 to $100 per acre to form. An average increase of 2 tons per acre over the unformed fields for both 1959 and 1960 is encouraging.

The quick acceptance of this practice by the sugar planters may be a little premature until some of the problems are worked out. Some of these problems are: (1) the most applicable slope for the work, (2) the field drain back slope to facilitate heavy cane machinery, and (3) row length versus slope.

ARS-SCS workshops for the SCS personnel working in the cane area have given the practice wider coverage. In 1960 additional areas were worked by cooperators of the Soil Conservation Districts, giving the practice wider coverage for observations and demonstrations.

Pasture Land

Two approaches are generally taken on the forming of pasture land. One is to corrugate it with graders, a practice developed by SCS. The other is to cut a series of flat sloped ditches with a scraper utilizing the earth to fill the depressions and then smoothing it with a land leveler. The ditches are generally cut with a very flat slope somewhere in the vicinity of 8-12 to 1,140 feet apart. The flat slopes facilitate the herding of livestock with automotive equipment. One test area on the LSU Ben Hur Farm was formed using this procedure in 1953. To date, it requires practically no maintenance other than mowing and reseeding. The carrying capacity has been beyond other fields, but authentic data are not available since it is being used for testing various seeding and fertilizer treatments. The cost of this particular work was approximately $60 per acre.

General Crop Land

As previously stated, the first work on general crop land was done to facilitate irrigation. In the latter year, however, it has been done primarily to facilitate drainage. More problems have arisen in adapting land forming to general crop land because of the large areas involved which require precision work. This is especially true for drainage. Most of these problems had to do with development of techniques for doing the work.

For those of you who have not gone through the growing pains of adapting land forming to the humid area, I will cover some of the phases of its development. When the work was first begun most land owners and technicians over-estimated the amount of land they could form during a given period. Three factors were responsible. First, the idle period of row crop land is short and is also the wet season. Second, the lush growth of vegetation was not considered, resulting in much wasted machine time. The Delta Branch Station at Stoneville, Mississippi reports an increased cost of $20 per acre for forming land under trashy conditions. Third, because of the amount of work scheduled in the limited amount of time available due to the first and second factors, a poor job of forming resulted.

The majority of the lands are now left idle for the land forming work, or an early-maturing crop, such as oats, is planted and the work is done in late summer. Crop residues are now disposed of before beginning the land forming work. Also, vegetation is controlled, usually by disking, during forming operations.

Suprisingly, the fill areas, rather than the cut areas, showed a crop retardation. Many theories, such as compaction, have been expounded on the crop retardation in the fill areas. Our experience has been that if we obtain an adequate forming job, retardation is minimized, provided the area is scarified or ripped before and after filling.

A good land forming job requires adequate fills, and precision in the transition from cut to fill. The fill areas settle and the cut areas fluff up during tillage operations, but field experience is gradually overcoming this problem. Using a rule of thumb method of providing adequate fills, we are purposely over-filling by .1 ft. on areas requiring .5 ft fill and over-filling by .2 ft. on fills above .5 ft. to allow for settling. In spite of this, a second working is usually required.

In planning the land forming, a 60:40 cut to fill ratio is adequate in most instances on a field that is reasonably firm. If the levels are taken when the field is not firm, this ratio would not apply and allowance should be made for additional shrinkage.

The tolerances allowed for the rough grading of land forming work should be tempered with field judgment. In most instances a .1 ft. tolerance is allowed. We are using a .05 ft. tolerance. The land leveler will not correct a large expanse with a .1 ft. tolerance during the finishing or smoothing operation, especially the short (30 ft.) land levelers common in the humid area.

In planning the land forming work the grade requiring the least yardage of earth to be moved was specified in most instances. This often resulted in many light cuts and grades of .1 per foot or less.

This soon proved to be false economy. The light cuts did not economize on machine time because the haul distance was exorbitant and light cuts are hard to obtain, resulting in much over-cutting.

Imperfections in the work and implement scars are more pronounced on flatter slopes. This has a large effect on the drainage. Wherever possible, most engineers are using a slope of .2 per 100 feet, which has been established from a practical standpoint, rather than any water flow criteria.

There is a wide variation in the amount of yardage required to form Louisiana delta lands. It ranges from 125 to 450 cubic yards per acre. Average haul distance is approximately 400 feet. In rare instances it is 1000 feet. The cost of grading ranges from 18 to 25¢ per cubic yard.

Earth-moving machines compact the soil, increasing the bulk density of the fill areas by approximately 0.10 grams per cubic centimeter (approx. 6-¼ lbs. per cubic feet). The area is ripped after smoothing to remove this compaction and to blend the fill with the original soil, which lessens the crop retardation. A heavy field cultivator with flexible chisel shanks is a good tool for this operation.

Land forming under certain conditions will even the crop production over a field. An approximate 22-acre test area at Newellton, Louisiana, which was in a deep tillage test in 1954, is a typical example. The results were affected by a ridge and slough condition, which introduced a drainage factor into the test. In 1955 the area was formed and in 1956 was put back into deep tillage, retaining the same locations for the conventional plots as in 1955. The yields in 1956 were much more uniform than in 1954.

	Lbs. Seed Cotton				
Year	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Range Between Low & High
1954	2545	1800	2034	1573	972
1956	3392	3261	3500	3076	424
				Difference	548

The major techniques of adapting and applying land forming to the humid area have been worked out and developed from a practical research standpoint. Typical of many other research studies, it raises as many questions as it answers.

Since land forming facilitates drainage, research must determine its effects on the component parts of a drainage system. In addition, a standard for measuring the adequacy of the practice, such as the water tolerance of crops for drainage, should be established.

The water tolerance of crops as a drainage standard is based primarily on field observations and assumptions. The present drainage design criterion of removing the surface water in 24 hours is inadequate since variations are observed in the field each year. In some instances crops have not been damaged when inundated for 48 hours, while others have been damaged in 12 to 15 hours. Therefore, a new standard should be established for all classes of crops, incorporating the effect of temperature, soil type, and the specific crop grown, to determine the adequacy of surface drainage and to evaluate its benefits. The Agricultural Research Service has work underway on this phase in North Carolina in cooperation with the State Experiment Station, on which Dr. van Schilfgaarde has already reported.

Ditch spacing can be widened and row length increased by land forming, reducing ditching and drainage maintenance costs. However, there is very little specific research data on ditch spacing and row length for various slopes on formed land.

The Soil and Water Conservation Research Division of Agricultural Research Service has experimental work underway on this problem in Virginia and Minnesota. An extensive experiment is also being established at Baton Rouge in cooperation with the Louisiana Agricultural Experiment Station, which we will visit on our Thursday field trip.

This experiment comprises some 80 acres of land, which is being formed in two replications. Each replication consists of four blocks of land and each block is being formed with a different slope, as follows:

1. .1 ft. per 100 ft.
2. .15 ft. per 100 ft.
3. .20 ft. per 100 ft.
4. .25 ft. per 100 ft.

Each block will be divided into four 84-foot plots with each plot having different row lengths, as follows:

1. 500 ft. long
2. 700 ft. long
3. 900 ft. long
4. 1100 ft. long

The entire experiment consists of 32 plots with a uniform sidefall of .05 ft. per 100 ft. The following data will be taken;

1. A series of wells will be established over the area to measure and record the ground water table.
2. A weather station will be established to measure precipitation, temperature, wind velocity, sunshine and evaporation.
3. Runoff measurements will be made using water stage recorders and calibrated flumes. Allied with the runoff measurements, silt sampling will be done to ascertain the extent of erosion.
4. Soil moisture and temperature will be measured.
5. Soil physical measurements will be made to determine bulk density, permeability, pore space and particle size analysis. These measurements will be used to catalog the area from a soil physical standpoint.
6, Hydraulic measurements of the furrows will be made to determine bulk density, permeability, pore space and particle size analysis. These measurements will be used to catalog the area from a soil physical standpoint.
7. Hydraulic measurements of the furrows will be made as follows: velocity, hydraulic gradient, perimeter, and coefficient of roughness.

Instrumentation

From the data of this experiment, the following information should be obtained:

1. Determine the maximum row length that can be used on formed and smoothed land as projected against slope for adequate drainage. Maximum row length will be the basis for determining the spacing of both field and quarter drains since the rows are crossed by field drains in cotton fields and by quarter drains in sugar cane fields.
2. Determine the amount and time of concentration of runoff for designing field drains and lateral ditches as related to row length and slope. This will also be used as a basis for lateral ditch spacing.
3. Determine the soil physical characteristics as a basis for extropolating the experimental results and their application to other locations. Determine the effects of drainage on soil temperature as projected against row length and slope.
4. Correlate the weather measurements of temperature, evaporation, and wind velocity with their effect on drainage.
5. Determine the hydraulic characteristics of the conventional furrow cross section to be used as a basis for future work in modifying the section to obtain better drainage.

One half of this experiment should be established and in operation in 1961.

Economics research on land forming was begun recently by the Division of Farm Economics of the Agricultural Research Service. This should give a monetary basis for evaluating land forming for both drainage and irrigation.

Since farm machines operate more efficiently and effectively on formed and smoothed land, a time study to evaluate the efficiency and the quality of the work should be conducted.

Often certain farm operations are quite timely in relation to the crop produced, especially in the fields of cultivation, weed control, land application of insecticides, and harvesting. Generally, land forming gives better drained fields, permitting farm operations to start sooner after rains. The economy effected by the time saved in this respect should be studied and evaluated.

Irrigation Research Other Places

Extensive research on the component parts of irrigation that affect land forming is underway in both humid and arid sections. Such information will be valuable when droughts necessitate irrigation.

Studies are underway in Missouri and Alabama on the hydraulics of water flow in furrow irrigation. The rates of advance and recession, velocity, coefficient of roughness and width of furrow stream as it affects the application of irrigation water, are being considered in these studies.

In the arid section extensive work is underway on the hydraulics of both furrow and border irrigation. Work is also underway in the arid section on water intake rates to determine rates of application for maximum efficient use of water in various soils.

Conclusion

This is a report on the progress of land forming research in the Lower Mississippi River Valley. Considering the scarcity of applicable information, farmers and agricultural workers have done an exceptional job of adapting land forming to the humid region. Many benefits are reported from field observations and farmers' testimonines. There have been some disappointments, but most of these have been caused by lack of precision work. This was especially true during the first year or two when farmers and contractors were learning how to establish the practice. As research progresses and more basic determinations are made, a much wider contribution to agriculture by land forming is inevitable.

CHARACTERISTICS OF FLOW IN IRRIGATION FURROW

by

John F. Thornton[1/]

The efficient use and distribution of irrigation water are predicated upon a knowledge of the behavior of water flow in irrigation furrows. Unfortunately, the interactions of flowing water and soils have been difficult to analyse, resulting in a general inability to express these interactions quantitatively and accurately. Only recently have researchers become aware of the need for more precise designs and descriptive mathematical expressions and have been encouraged to study the basic variables and fundamental principles of the hydraulics of furrow irrigation systems. This study is needed to describe or define some of the basic hydraulic aspects of flow in irrigation furrows, to contribute to a better understanding of furrow irrigation and the ultimate achievement of more efficient use of water.

The study being conducted at Columbia, Missouri, is concerned with two aspects: the flow of water from irrigation furrows into the surrounding soil and the hydraulics of flow in small channels.

The former involved the determination of the influence of furrow shape, size, and slope on the infiltration of water into the soils. Particular emphasis will be placed on infiltration theory and improvements in the techniques of measuring infiltration.

The relationships between flow rate, flow velocity, furrow shape, furrow slope and hydraulic roughness will be determined for different soils.

The study involves the integration of all the physical factors into a mathematical expression whereby the distribution efficiency of furrow systems will be made optimum.

The general procedure being used involves definitions of the several hydraulic phenomena under controlled laboratory conditions. At the conclusion of these tests, it is anticipated that field evaluations will be necessary which will in turn permit irrigation system design criteria to be developed. Facilities available for the work include a tilting flume, 3.33 feet wide and 30 feet long. Original equipment to simulate infiltration of water from the flume is completed but has not been used.

Internal properties of the flowing water are not considered variables in these tests, but are assumed constant since water temperature remained between 65 and 70° F. during most of the tests. It was observed that the magnitude of normal depths in a given channel is determined by stream size, channel roughness and slope. For distances greater than a few feet behind the front, the manner in which normal depth is approached in a given channel is affected by distance and slope but is essentially independent of stream size in the tests thus far accomplished.

1/ Research Investigations Leader, ARS-SWC, Columbia, Missouri.

Tests were run with varying flow rate and slope on smooth aluminum. Materials will be added to the aluminum to give various values of "n". Also an intake rate will be artificially applied to the model.

In twenty-five tests where Q varied from 5 to 80 gpm and the slope varied from .125 to 2 per cent, the "n" factor for the smooth aluminum furrow model was found to be .0063.

The rate-of-advance equations for the smooth aluminum model varied between

$$y = 25.0\ x$$

and

$$y = 125.0\ x$$

where y = distance in feet and x = time in minutes.

The first of these equations was for Q=5 gpm and S = .125%. The last of the two equations was obtained for Q = 80 gpm and S = 2%. A general form of the rate of advance equation is $y = m\ x^n$. For these model tests, n was constant at 1 and m varied with both slope and flow rate.

A vertical model of a soil profile was set up in the laboratory to measure intake rates. Knox silt loam was used in all three tests. The soil sample was screened and mixed to a uniform moisture content equivalent to 15 atmosphere suction. Amounts sufficient for a 2 cm layer in the model were weighed and compacted in the model to a bulk density of 1.35.

The mechanical analysis and release curves data for Knox silt loam are shown in Tables I and II.

Table I. Mechanical Analysis of the Three Different Layers of Knox Silt Loam

		Silt		
Test No.	Clay	Fine	Course	Sand
1 (18-30 inch)	26.0	24.75	40.0	9.25
2 (6-18 inch)	17.0	25.5	41.2	16.3
3 (36-48 inch)	18.9	29.6	47.5	4.0

Table II. Moisture Release Curve for Knox Silt Loam

Tension	(18-30 inch layer) Moisture	(6-18 inch layer) Moisture	(36-48 inch layer) Moisture
ATM	P_W	P_W	P_W
0.10	38.5	33.2	38.0
0.33	27.0	25.9	25.1
1.00	18.6	19.9	18.9
3.00	15.7	16.6	14.8
15.00	11.6	12.2	11.4

Studies of furrow intake in the model resulted in intake equations in the form $i = a\ t^b$ where i is the intake rate in inches/hour at time t, and a and b constants. The effects of water depth and furrow shape on this equation will be evaluated by the regression analysis to see whether these factors are related linearly to intake rate.

The equations for intake rates were as follows:

Test 1 $i = 3.29\ t^{-0.69}$

Test 2 $i = 4.14\ t^{-0.47}$

Test 3 $i = 4.64\ t^{-0.69}$

The equation for the intake of each of the layers of soil was very different. The sand content of the soil seemed to have more to do with the intake rate than clay content.

The hydraulic conductivity for saturated flow for the four tests are as follows:

Test No.*	K_W cm/hr.	Moisture Content at start of tests %
1-A	0.49	11.2
1-B	0.11	27.0
2-A	0.86	12.2
2-B	0.43	25.9

* A - dry runs

B - wet runs

The equation for hydraulic conductivity for the first test was $K_W = e^{(-12.1 + 0.25 P_V)}$, and for the second test, $K_W = e^{(-11.8 + 0.23 P_V)}$.

The equations for the rate of advance of wetting front through a soil profile where the soil was at the wilting point initially are shown as follows:

Test No.	Equation*	Time required to move 204 cm in soil profile hours
1	$d = 3.75\ t^{0.54}$	164.5
2	$d = 4.08\ t^{0.62}$	87.5
3	$d = 4.90\ t^{0.50}$	344

* d - rate of advance of wetting front
t - time in hours

Gravity seemed to show a greater effect on the rate of advance of the wetting front on the layer of soil with a higher sand content. The head of water and the temperature of the water were held constant throughout all tests.

Engineers should recognize that these tools will provide the key for optimum design of furrow irrigation system and efficient, economic water use and distribution; and will provide the basis upon which automation may be applied to furrow irrigation systems.

THE EFFECTS OF LAND-FORMING PROCEDURES ON SOIL COMPACTION

by

Phelps Walker and J. H. Lillard[1]

The compaction and manipulation of soil during land-forming operations result in temporary depressions in crop yields and increased power requirements to till formed land. Both of these factors contribute to the total cost of land-forming operations and must be considered by the farmer in financing his land-forming program. Therefore, several investigators of surface drainage problems have given some consideration to measuring the degree and duration of yield depressions as the result of land forming and to methods of restoring compacted soil to good tilth.

The purpose of this report is to present a summary of the results from the soil compaction studies conducted in Virginia.

The soil compaction studies in Virginia involve parts of three field experiments. The first is a measure of the effect of land-forming operations on bulk density, percolation rates and soil porosity in an Atlantic Coastal Plain soil-Elkton very fine sandy loam. Following the completion of the earth-moving and smoothing operations, 3-inch core samples were collected from cut (soil removed), fill (soil deposited), and neutral (neither cut nor fill but receiving machinery traffic) areas at both the new land surface and the 5- to 8-inch depth. The control area, which received no soil movement or machinery traffic, was also sampled at the same time.

The effects of soil compaction during the initial land-forming operations on bulk density measurements are summarized in Table 1. Statistical analyses of these data show that the soil density in the cut areas is greater than the densities in the fill and neutral areas but is not different from the density in the control plot and the 5- to 8-inch depth. Also, the surface soil density in the fill areas is slightly higher than the density of the surface soil in the control plot. These measurements appear to point out that, for this soil condition, manipulation of the soil and machinery traffic are responsible for a slight increase in soil density, but the largest increase of surface soil density is the result of uncovering the more dense subsoil.

The compacting forces acting upon the soil during forming operations have little effect on the soil percolation rates except near the soil surface. Data presented in Table 2. show that percolation rates for the surface of formed plots are 1.3 iph, while that for the control plot surface are 3.3 iph. Differences between average for formed plots and the control plot are not significant. The lower surface percolation rates have been attributed to the grinding of fine material into the soil during the final smoothing operations.

Similar observations are found in the soil porosity data.

1/ Agricultural Engineer, USDA, and Professor, Agricultural Engineering Research, Virginia Polytechnic Institute, Blacksburg, Virginia, Respectively.

Table 1. Effects of land-forming practices on soil compaction as reflected in bulk density measurements

Item	Treatment			
	Cut	Fill	Neutral	Average
Graded plots	1.44	1.35	1.36	1.38
Control plots				1.37
Position				
Surface				
Graded plots	1.45	1.32	1.32	1.36
Control plots				1.28
Depth - 5" - 8"				
Graded plots	1.43	1.38	1.40	1.41
Control plots				1.46

Table 2. Effect of land-forming procedures on soil percolation rates

Item	Treatment			
	Cut	Fill	Neutral	Average
	iph	iph	iph	iph
Graded plots	2.6	2.5	1.4	2.1
Control plots				2.5
Position				
Surface				
Graded plots	1.8	.7	1.2	1.3
Control plots				3.3
Depth - 5" - 8"				
Graded plots	3.3	4.1	1.5	3.0
Control plots				1.6

The initial plowing of the plots after forming was difficult and could not be performed except when the soil moisture was slightly above the maximum recommended for tillage. While no draft measurements were made, it appeared that the areas requiring the most power to pull the plow were coincident with the areas of higher soil bulk densities.

The last observation led to the second phase of the study--the measurement of power requirements for tilling formed land. A special apparatus, locally referred to as a soil hardness indicator, was developed for this study. This machine measures the force required to pull a well-defined chisel through the soil at several depths between 3 and 11 inches and provides a direct measure of the compacting effects of the land-forming machines on the soil.

Draft measurements were made in a river bottom soil in the Piedmont Region for the following treatments:

1. Cut areas vs. fill areas.
2. Bare formed soil vs. formed soil scarified 3 inches deep immediately after forming.
3. Soil immediately after forming vs. soil 5 to 7 days after forming.
4. Depth at 3 in. vs. 7 in. vs. 11 in.

Tilling of the soil three inches deep with field tiller reduced the power requirements for final tillage from 540 pounds to 355 pounds--a 34 percent reduction. Power requirements increased with depth from 77 pounds at the 3-inch depth to 402 pounds at the 7-inch depth, and to 864 pounds at the 11-inch depth. Significant differences in soil moisture occurred between the 3-inch depth and the 7- and 11-inch depths (17.8 percent and 22.3 percent, respectively). Differences in soil moisture for the other treatments were not large enough to affect the draft measurements.

Tilling the soil 5 to 7 days after the completion of forming operations required the same force as that for tilling immediately after forming the land.

Tilling the "cut" areas required 478 pounds of force, while that of the "fill" areas was 416 pounds. Although this difference in force does not test significant, the decrease in power required to till the "fill" areas is the reverse of the observations made during plowing several months later. It was noted as the soil was plowed that soil in the fill areas broke into large clods and that somewhat more power was required. This discrepancy between measured and observed power needs for tilling may be attributed to different soil moisture conditions at the time of observations or it may point out the need for further refinement of the measuring techniques.

The third phase of the soil compaction studies is the measurement of crop yield response on formed land. This study is still in progress on both the Coastal Plain and the Piedmont river bottom soils. In the first corn crop harvested from the Coastal Plain plots, the 1959 crop, the control plots outyielded the formed plots 124 bushels per acre to 116 bushels per acre. The trend reversed in 1960 when the yield was 96 bushels per acre on the formed plots and 88 bushels per acre on the control. The 1960 corn crop was the first to be grown on the river bottom test site, and the average yield on the formed plots was 107 bushels per acre.

A breakdown of grain yields within the formed plots is given in Table 3. Corn yields from cut areas of the fine-textured Coastal Plain soil were 9 bushels per acre (7 percent) less than those from the fill areas in 1959, but only 4 bushels per acre (4 percent) less in 1960. The later difference does not test significant. Corn yields from the cut and fill areas in the river bottom in 1960 were equal for the fine-textured soil but yield from the cut areas in the coarse-textured soil was 15 bushels per acre (14 percent) less than that from the fill areas. While not measured, these observations were noticed in previous experiments. In these cases, yield depressions seemed to disappear after the third crop year.

Table 3. Corn yields from cut and fill areas of coarse and fine-textured soils - Virginia 1959-60

Item	Cut		Fill	
	1959	1960	1959	1960
	bu./ac.	bu./ac.	bu./ac.	bu./ac.
Coastal Plain				
Fine-textured	112	94	121	98
Piedmont River Bottom				
Fine-textured	-	106	-	106
Coarse-textured		94		109

Summary

Tests conducted in a fine-textured Coastal Plain soil near Norfolk, Virginia, show that soil manipulation during land-forming operations and the accompanying machinery traffic cause a slight increase in soil density; however, the density of the subsoil uncovered in forming the new grade has a much higher density than the original soil. Other tests in a river bottom in the Piedmont Region indicate that the power required to till formed land can be decreased by more than 30 percent if the soil is scarified immediately after forming. Initial depressions in crop yields from 7 to 14 percent have been measured; but, with good soil management, depressed yields disappear in two to three years.

DRAINAGE RESEARCH AT THE UNIVERSITY OF ARKANSAS

by

Warren S. Harris[1/]

Introduction

The University of Arkansas has had a drainage research project in effect since September, 1958. The original project was based largely upon tile drainage investigations. This project was terminated at the end of June, 1960, and the present project was put into effect. The prime objectives of the present project are to determine the physical requirements for adequate surface drainage of row crops.

Tile Drainage Investigations

The author presented a paper titled "Tile Drainage Investigations in the the Arkansas Delta" at the Southwest Section Meeting of the ASAE in March 1960. The gist of this paper was that tile drainage studies were being dropped at the University of Arkansas because an engineering investigation indicated that there were no locations in the delta area where tile drainage would be effective.

Delta soils do not lend themselves to tile drainage. This can be illustrated by the following: unsaturated, freely permeable substrata that lie as close as four feet below the soil surface and are, in effect, equivalent to continuous subdrains do not exert a readily detectable effect upon crops or crop production. The texture, structure and stratification of delta soils are such that the surface four feet or less of soil will determine internal drainage characteristics.

Delta topography does not lend itself to tile drainage. High normal water tables occur only in areas where surface drainage is inadequate and the lack of adequate surface drainage fails to provide outlets for tile drains.

Many tile systems have been installed in the Arkansas Delta. To the best of the author's knowledge not one of these systems has had an appreciable effect upon internal drainage. In isolated cases tile drains have been effective, for a period of time at least, as improvements to surface drainage via surface inlets.

Row Drainage

In 1959 row drainage studies were begun. Both the Soil Conservation Service and the Extension Service have cooperated in these studies. SCS and Extension personnel with engineering backgrounds aid in making observations concerning the physical properties of the rows. Non-engineering personnel have proved helpful beyond all expectations in observing factors not directly related to drainage such as disease and insect damage.

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The procedure followed is simple. In May and June of each year individual row, or more specifically middle, profiles are surveyed and plotted. Readings are to the closest 0.05 foot. In the fall the rows are walked and in some cases rows or portions of rows are resurveyed with readings taken to the closest 0.01 foot. Observations concerning the adequacy of drainage are made in both the spring and fall.

Cotton has been chosen as the indicator crop. Soybeans are more tolerant to water than cotton, hence are poorer indicators. Other row crops do not occur in sufficient abundance to warrant study at this time.

Three signs of inadequate drainage have been observed: Reduced stand and/or yield, interference with or delay in mechanical farming operations and excess weed and/or grass growth.

Surface depressions and restricted outlets were found to be major causes of inadequate drainage. Depressions as shallow as 0.05 feet were found to have an undesirable effect upon drainage in clay soils and in silt soils with poor internal drainage. In silt and sand soils with good internal drainage, depressions as shallow as 0.10 feet had an undesirable effect. Restricted outlets are similar to surface depressions in that both pond water.

In no case has it been possible to isolate grade, length of row, uniformity of grade or any combination thereof as causes of inadequate drainage. Rows having average grades of 0.05 feet per 100 feet or less and lengths of 1,000 feet or more have been observed on both clay and silt soils. Rows having lengths of 1,600 and 2,100 feet and average grades exceeding 0.05 feet per 100 feet have been observed on clay and silt soils, respectively.

Rill erosion has been observed on all soils on grades steeper than 0.50 feet per 100 feet but less than 1.00 foot per 100 feet and immediately above abrubt changes in grade. Stated conversely, rill erosion has not been observed on grades of 0.50 feet per 100 feet or less except in conjunction with abrubt changes in grade.

Deposition invariably occurs downslope from rill erosion. Deposition may occur within the row on a flatter grade or it may occur in the outlet ditch.

No observations have been made concerning sheet or splash erosion.

Delta topography does not provide rows of unlimited length, etc., therefore, the above statements must be qualified in that only conditions typical to the delta have been observed.

A more complete coverage of the row drainage studies is contained in an article titled "Row Drainage Studies in the Delta Area" which appeared in Vol. IX, No. 6 (November-December 1960) of Arkansas Farm Research, a publication of the Arkansas Agricultural Experiment Station.

Field Drainage

In 1960 a study was begun to determine the physical requirements of surface field ditches. The problem was approached in this manner: the requirements of the ditches were defined, specifications were written to meet the requirements, ditches were and are being built to meet the specifications and the ditches will be observed for effectiveness.

Five interrelated requirements were considered important. These are listed below without reference to relative importance:

1. Provide adequate drainage
2. Minimize maintenance
3. Minimize rill erosion and resulting mud bars
4. Facilitate mechanization
5. Eliminate idle areas and resultant weed patches

The conclusion was reached that if a field sized area has continuous grade and the various components of the drainage system are readily maintained with ordinary farm equipment, the field will have adequate drainage. Free outlets to main drainage systems are assumed. Temporary surface storage and overland flow parallel to some of the drainage ditches are considered to be a normal part of the operation of drainage.

If the above conclusion is correct, factors other than hydraulics and hydrology should determine the magnitude of the recommendations within a drainage guide. Further, a single guide should be applicable to all delta soils. An experimental guide in the form of a "Row Crop Drainage Guide" has been prepared based on the above assumptions. Copies of the guide are available, therefore, it will not be reproduced here.

One ditch has been constructed across rows at the N. E. Branch Experiment Station at Keiser. It is 2500 feet long and drains 37.4 acres. The drainage area, 660 by 2600 feet, has been put to grade. The lower 1300 feet of the ditch is across a segment having zero side slope. The ditch is approximately a foot deep at the outlet. Inasmuch as the ditch was placed along a line that crossed a natural swale a large quantity of fill was required for a levee which was constructed downslope from the ditch. This ditch was expensive to build but this is not a normal situation.

One ditch parallel to the rows has been constructed on the N. E. Branch Station. This ditch is 1300 feet long and drains 35 acres, 20 acres of which has been put to grade.

Additional ditches will be constructed in 1961 on the N. E. Branch Station at Keiser and on the S. E. Branch Station at Kelso.

In 1960, two major conclusions were reached concerning the guide, First, surface field ditches can be readily constructed on grades as flat as 0.05 feet per 100 feet by semi-skilled operators using small dirt movers and land planes. Close supervision is required. Second, as an aid to construction, surface field ditches parallel to rows should have a minimum bottom width equal to the length of the blade on a land plane. This bottom width should ease maintenance requirements and facilitate mechanization in addition to facilitating construction.

Observations in 1961 indicate that a grade of 0.30 feet per 100 feet in a surface field ditch will be subject to erosion. This erosion may not be of a serious nature but the resultant deposition will be serious. A segment of the 2500 foot ditch intercepting rows eroded on a 0.30 feet per 100 feet grade with a drainage area of less than 10 acres. Resultant deposition within the ditch pocketed water at the ends of adjacent rows.

As mentioned above, copies of the "Experimental Row Crop Drainage Guide" are available. The guide is not for general distribution and does not reflect unqualified recommendations for field use.

Land Grading

The land grading work being done in connection with the drainage project is on a cooperative basis with Billy Bryan who is doing research in irrigation.

From a drainage standpoint the grading studies have two objectives. The first one is to verify the "Row Drainage Studies" as a practical design tool. The other is to study design and construction techniques in terms of economy of time and capital.

In the author's opinion the most economical and easily attained grade is that one which most closely conforms to the natural topography providing cuts and fills are not excessive and providing the work is done by competent operators using good equipment. In other words a very flat grade costs less and is more easily attained where cuts and fills are light than a steeper grade that involves heavy "cutting" for grade. Further, a non-uniform but continuous grade involving light cuts and fills costs less and is more easily attained than a uniform grade involving heavy cuts and fills. Drainage design on the various stations is based upon this opinion.

To be practical finished fields must be irrigable and lend themselves to mechanization. Erosion that constitutes a serious economic loss cannot be tolerated. When design on typical delta soils and topography is based upon economic justification rather than theoretical optimums the various design requirements seem to tend to compliment each other rather than to conflict with each other.

At the S. E. Branch Station 35 acres of Perry Clay is to be put to a continuous but nonuniform grade that ranges from near zero to 0.10 feet per 100 feet. The author is not sure whether this is a land smoothing, grading, leveling or forming job. It depends upon your definition. The area will be gridded on a 100 foot centers. The objectives are to eliminate pot holes and to give the ground a continuous fall. Maximum cuts and fills will not exceed 0.20 feet. Maximum row length will be 1300 feet. A single surface field ditch will drain the area.

At the N. E. Branch Station land is being put to non-uniform grades in an effort to lower construction costs while achieving the objectives of land leveling. No grades flatter than 0.10 foot per 100 feet have been constructed on this station because, generally speaking, natural average slopes do not fall in this range.

The author and Cedric Lee, a contractor from Tillar, Arkansas, are preparing a paper for presentation at the June meeting of the ASAE titled "Procedures in Land Leveling Design". This paper proposed that maximum advantage be taken of natural topography in design in an effort to lower construction costs. Copies of this paper will be available at the ASAE meeting and, upon request, after the meeting.

Conclusion

The discussion above covers the main drainage studies now being conducted at the University of Arkansas. Future plans call for the expansion of the above studies and for the initiation of new studies.

At present plans are to publish, in bulletin form, the results of the row studies in the spring of 1963. Additional material will be published when it is deemed ready.

University of Arkansas
Experimental
ROW CROP DRAINAGE
GUIDE

The "Experimental Guide" is intended for use in conjunction with drainage research being conducted by the Agricultural Engineering Department of the University of Arkansas. The guide was prepared in 1960, revised in 1961 and is subject to further revision.

Preliminary investigations have led to the conclusion that field sized areas in the Arkansas Delta and bottom lands will have adequate drainage if they have "continuous" grades and if the various drains can be readily maintained with ordinary farm equipment. Continuous grades will provide "dry bottom" drains and the cross section requirements for maintenance will guarantee adequate capacity. As used herein "continuous" indicates no reverse grades and "dry bottom" indicates that the various drains will dry out more or less uniformly barring major soil variations.

If the above conclusion is correct, factors other than hydraulics or hydrology should determine the magnitude of the recommendations for the various drains. Further, a single guide should be applicable to all poorly drained delta or bottomland areas in Arkansas regardless of soil types. On the basis of these conclusions, recommendations are based upon economic feasibility, practical construction tolerances and maintenance requirements.

The guide assumes a free outlet or outlets into a major drainage system. It also assumes temporary storage on the surface of the fields and limited overland flow at times of peak runoff. These assumptions are basic and are common to almost all if not all modern drainage guides.

Design capacity in the form of a drainage coefficient is specified for field laterals because these ditches normally do not meet the cross section requirements that guarantee adequate capacity. Field laterals may be, but ordinarily are not, maintained as "dry bottom" ditches. They require special maintenance for weed and grass control because they cannot be cultivated readily with ordinary equipment at the same time that adjacent field work is being done. Field laterals have two major advantages over surface field ditches parallel to rows. First, they are less costly to construct when depth becomes excessive. Second, they can be constructed in seasons when field conditions prevent the construction of surface field ditches. To facilitate construction ditches may be constructed as field laterals and later converted to surface field ditches.

Length in itself is not considered to be a limiting factor for any of the drains listed in the guide. Natural topography and recommended depths, grades and side slopes will determine the length in any given situation.

An abrubt overfall at the outlet of a surface field ditch is an obvious violation of grade limitations. It is assumed that drop structures will be used in such locations.

Seepage of surface water will not continue for extended periods of time after rainfall ceases if the recommendations in the drainage guide are followed over the entire watershed. However, seepage from rice fields or from areas not drained as recommended can saturate a ditch bottom for long periods thereby invalidating the "dry bottom" concept. Such seepage is justification for recommending field laterals in locations where surface field ditches parallel to rows would ordinarily be constructed.

Drawings are included with the guide to illustrate construction details and the relative locations of the various drains.

Type of Structures	Drainage Coefficient	Depth Min / Max (feet)	Minimum Bottom Width (feet)	Spacing	Grade Min / Max (ft/100 ft)	Side Slope Min / Max (ft/ft)	See Note No.'s
Field Laterals	$Q=40M^{5/6}$	1.0 / --	4.0	660. to 2640.	continuous non-erosive	1/1	1,2 3,4
Surface Field Ditches Parallel to Rows	None	0.5 / 1.5	8.0	660 to 2640	0.05 / 0.30	6/1 / --	3,4
Surface Field Ditches Intercepting Rows	None	0.25 / 1.0	--	As Required	0.05 / 0.30	100/1 / 400/1	5,6, 7
Levees	None	Height 0.5 / --	--	--	-- / --	10/1 / --	5,7, 8
Water Furrows	None	-- / --	--	As Required	continuous / 0.50	-- / --	9
Rows	None	-- / --	--		continuous / 0.50	-- / --	10

NOTES:

1. In the drainage coefficient, "Q" equals the design quantity of flow in cubic feet per second and "M" equals the drainage area in square miles. The so-called "Delta" curve is derived from this equation when the constant, "40", is used as indicated.

2. Add 0.5 feet freeboard to design depth of field laterals when the design grade is less than 0.05 ft/100 ft.

3. Field laterals and surface field ditches parallel to rows should have levees of sufficient height to prevent inflow except at surface field ditch or water furrow junctions.

4. Surface field ditches parallel to rows may replace of grade into field laterals.

5. Surface field ditches intercepting rows may be single or double. Generally speaking, single surface field ditches should drain rows from only one direction.

6. The minimum side slope of 100/1 equals a grade of 1.0 ft/100 ft., and the maximum side slope of 400/1 equals a grade of 0.25 ft/100 ft.

7. Levees should be located downslope from surface field ditches to control overland flow and/or to provide a place to "spoil" small amounts of dirt in routine maintenance operations. A double surface field ditch may be thought of as two single surface field ditches with a common levee.

8.. Levee height refers to single field ditches only.

9. Water furrows are considered to be a temporary measure only. For proper drainage either they should be replaced with surface field ditches or the depression should be eliminated by land forming.

10. Row grades within the range of 0.10 to 0.30 ft/100 ft and side slopes flatter than row grades are preferred.

RESTORING FERTILITY OF LAND DENUDED OF TOP SOIL

by

Perrin H. Grissom[1/]

The assigned title carries with it the connotation that soil fertility is depleted when land is denuded of top soil and that the fertility requires restoration. This interpretation may not be applicable to most of the soils of the Mississippi Flood Plain. In many of these soils there is little evidence of horizonation and in others horizons are poorly defined. Thus, it is difficult to define top soil in the Mississippi Delta. In many cases the only difference between top soil and subsoil may be simply a matter of aeration and organic matter content.

This report does not adhere to the topic assigned but presents results and observations of land grading and/or land leveling which has been accomplished in the Delta area of Mississippi. A project was initiated at the Delta Branch of the Mississippi Agricultural Experiment Station in 1955 to evaluate the effect of cutting and filling, involved in a land grading operation, on crop performance. In addition to farms included in detailed study several other farms were studied in a less intensive manner. The results, although not well documented, are as follows:

1. Cotton yields in the first year after land grading on 16 farms with moderately well to well drained soils showed no difference between cuts, fills, and neutral areas. The cut areas varied from .3' to 2.5' with an average cut of .7'. Fill areas ranged from .2' to 2' with an average of .7'.

2. Yield determinations on clay soils showed no differences between cuts, fills, and neutral areas.

3. On silt loam soils with poor internal drainage where 4 to 6 inches of well drained soil was overlying poorly drained silty clay material, heavy cuts sharply reduced yields. In one case the yield of cotton on neutral areas averaged 2214 pounds of seed cotton per acre and where cuts of .8' were made the yield was 248 pounds of seed cotton per acre. Subsequent observations of this farm indicated that uniform growth and yields prevailed in the third crop after the grading operation.

4. There were a few areas where heavy cuts were made on a fine sandy loam soil with good to slightly excessive internal drainage and loamy sand material was exposed. This resulted in poorer crop growth and yields than neutral areas.

5. When fields which have been graded are compared with undisturbed fields there is evidence that the graded fields are somewhat more susceptible to drouth and require earlier irrigation. This is true on cuts, fills, and neutral areas alike and is attributed to compaction, surface or otherwise, which occurred during the grading operation.

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6. Observations of fields which were graded when the moisture content was high show considerably more compaction difficulty than when a lower moisture percentage prevailed.

7. As a generalization, plant growth on fill areas has been somewhat less than the growth on cut areas. The compaction problem appeared to be aggravated during the fill operation, especially where it is done without disturbing the soil surface before making the fills.

8. Chiseling or deep tillage after soil movement is completed and planing is done should be considered an integral part of a land grading operation.

9. On loam and silt loam soils, in particular, cut areas are more susceptible to crusting and are more difficult areas to secure a stand than on neutral areas during the first year after grading. This is attributed to changes in surface organic matter content. As an example, at the Delta Station the organic matter content of the surface before cutting was 1.4% and after cuts were made it was .82%. Yields were not affected.

10. In some instances on loam to sandy loam soils cuts have exposed areas of soil deficient in sulfur.

11. Between 300 and 400 acres have been graded at the Delta Station with an average movement of soil ranging between 350 and 400 yards per acre. Fields have been graded to slopes of .1, .15, .2, and .4' per 100 feet. Accurate evaluation is not possible but slopes of .1 to .2 appear to be optimum on most soils except on clay soils. On clay soils drainage requirements are predominant and slopes of .2 to .3' per 100 feet appear to be optimum.

12. Finally, on most soils in the Delta area of Mississippi, land grading appears feasible if not ultimately essential, and can be done in most cases without harmful effects to subsequent crops. All land grading should meet both drainage and irrigation specifications.

DRAINAGE RESEARCH ON FOREST WETLANDS IN THE SOUTHEAST

by

Courtland E. Young, Jr.[1/]

The Charleston Research Center, Southeastern Forest Experiment Station, has the responsibility for forest wetland research in the Southeast. Current personnel working on the project include two research foresters and a research agricultural engineer. Future plans for personnel include a soil scientist, plant physiologist, and entomologist.

Wetland areas under consideration for research are river bottomlands, flatwoods, savannas, swamps, ponds, low coastal lands, upland bays, and pocosins. Many of these wetlands are very unproductive, either from the lack of established stands or low quality hardwoods growing on the area.

It is certainly not the aim of the Forest Service to try to establish criteria for converting all wetlands to pine. Rather, the prime objective is to determine the most productive and suitable tree species for each wetland site, whether the site is altered or unaltered by drainage.

Research in this field is directed toward determining the correct plant-soil relationships for optimum survival and growth of major tree species native to the Southeast. Once information along these lines is available, management practices such as drainage can be carried out to achieve these ends.

At the present time the variables being evaluated in conjunction with tree growth are grouped under: (1) water conditions and (2) soil physical properties. Water conditions being evaluated are water table fluctuations, vertical and horizontal water pressures, moisture tensions above water tables, and soil moisture changes above water tables. Soil properties being evaluated are aeration, conductivity, and oxygen diffusion on a range of soil types.

Established research studies cover only a few of the above mentioned variables over a range of wetland conditions. Further studies will expand and investigate further this type of research.

Research is also planned to classify more thoroughly the problem areas; i.e., topography, seasonal water table variations, geology, and type and extent of vegetation. Information of this nature will enable sounder drainage design to achieve certain desired plant-soil relationships.

More distant research objectives include obtaining information from a water balance of a typical wetland watershed. A drainage system established on this watershed after a number of years of measurement of water balance will provide a test of the effect of desired drainage needed to achieve certain plant-soil conditions.

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The effect of controlled water tables, water temperatures, and water movement on tree growth and survival hold an important place in future research.

Model studies to evaluate the effectiveness of certain drainage systems under varying watershed conditions hold merit in our future work.

Use of rainfall records is planned in determining and predicting wetland conditions. This technique will be incorporated in the over-all plant-soil environment approach to determine tree species adaptability.

Briefly this discussion has covered the problem areas involved in wetland forest research and the research techniques under way and planned to solve these problems. Research results will be made available to action agencies as soon as possible but the nature of tree growth delays answers longer than the same type of research on agricultural crops.

RESEARCH IN THE ECONOMICS OF LAND FORMING

by

Gordon D. Rose[1/]

Several statements regarding research needs have noted the need for more information concerning the economics of land forming. Particular reference has been made to the need for cost and benefit information for specific land-forming practices. This need is probably felt more urgently by the people in action agencies, as such information is essential in advising individual farmers as to the type and extent of land-forming measures that can be undertaken profitably. The Farm Economics Division in the newly organized Economic Research Service of the U. S. Department of Agriculture set up a study of the economics of land forming in 1958, with the advice and suggestions of the Soil and Water Conservation Division of the Agricultural Research Service. The general objective of the project is to determine the economic significance of various land-forming techniques for increasing the efficiency of utilization of the agricultural water resource in selected Eastern States. Specific aims are: (1) to determine the general nature and extent of land-forming activities as related to climatic, topographic, soil, and other physical factors; (2) to determine investment and maintenance costs and benefits in selected representative areas; (3) to develop a classification of land forming that will relate physical factors to economic feasibility; (4) to identify watershed and interfarm relationships of land-forming activities and explore solutions to problems arising therefrom; (5) to estimate the economic significance of land forming to agricultural production potentials and to future land and water use.

The project is being carried out presently in cooperation with the Iowa Agricultural and Home Economics Experiment Station. Up to this time, emphasis of the study has been on "cut and fill" terracing activities in Iowa. Immediate plans are to develop a linear programing analysis of "cut and fill" terraces. If the methodology seems feasible, efforts will be made to adapt it to the economic evaluation of other land-forming practices.

Economic research in land forming necessarily depends upon the research findings of physical scientists. This creates a need for closer working relationships between economists, engineers, and agronomists. A desirable approach would appear to be interdisciplinary efforts, in which complete physical and economic analysis of land forming could be carried out simultaneously. In this way, both the physical and economic aspects of land forming could be studied and more closely related. This approach should result in valuable information for use by action agencies and individual farmers.

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PROGRESS IN FUNDAMENTAL SOIL-WATER RELATIONSHIP NECESSARY TO PROVIDE ANSWERS FOR SURFACE DRAINAGE REQUIREMENTS, INCLUDING DRAINAGE REQUIREMENTS AND SUBSURFACE DRAINAGE OF CROPS

by

W. A. Raney[1]
(Interpretation by Phelps Walker)

Dr. W. A. Raney also appeared on the program but had no prepared release. My interpretation of his remarks appear below. Dr. Van Schilfgaarde was absent from the meeting. Mr. Gordon Rose, Economics Research Service, Ames, Iowa, was present at the meeting and made a few brief remarks, a summary of which is also given below. Two papers were carried over from the morning session and given during the afternoon. However, Mr. John Thornton, the Secretary for the morning session, collected the papers from both of those.

REMARKS: Raney - Progress in fundamental soil and water relationships are necessary to provide answers for surface drainage requirements, including the water tolerances of crops. Research now underway by the ARS and cooperating agencies is concentrated on such factors as climate, precipitation, soils, soil management-crop relationships and other factors related to ultimate solution of the problems connected with soil drainage. Dr. Raney then showed a series of slides indicating the location of the various research projects which ARS is either conducting or cooperating in. In addition he furnished the following bibliography of publications on this subject:

1. Drainage of Agricultural Lands. A joint publication by the American Society of Agricultural Engineers and the Soil Science Society of America.

2. Physical Characteristics of Some Representative Louisiana Soils. USDA ARS 41-33. Jan. 1960.

3. Supplement to Physical Characteristics of Some Representative Louisiana Soils. USDA ARS 41-33-1. Mar. 1961.

4. Soil Moisture Survey of Some Representative Missouri Soil Types. USDA ARS 41-34. Apr. 1960.

5. Low Cost Subsurface Drainage Installation. C. D. Busch and T. W. Edminster. Contribution from SWC, ARS, USDA, in cooperation with Dept. of Agr. Engr., Cornell Univ. Presented at Seventh Annual Meeting of Building Research Institute, Washington, D.C., Apr. 21-23, 1958.

6. Field Comparison of Tile and Surface Drainage. G. O. Schwab. Dec. 1960.

7. How Much Water Do Drain Tiles Remove? G. O. Schwab. Ohio Farm and Home Research. Mar.-Apr. 1961.

1/ Soil Physicist, ARS-SWC, Beltsville, Md.